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Use of Information Technology Tools in Source Selection Decision Making: A Study on USAF's KC-X Tanker Replacement Program

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The source selection phase in government acquisitions is so complicated in nature because it involves multi-criteria decision making that is supposed to respond to various requirements and subjectivity is usually inevitable in this kind of a decision making process. The purpose of this project is to demonstrate how the USAF's current source selection method (color rating method) is incompetent in showing small differences between proposed products, how this inadequacy leads to subjective decisions, and that the use of information technology tools can augment objectivity in this process.

In this study, USAF's KC-X Tanker Replacement Program has been selected as the program to be used to frame the research questions. Two models with two versions built on Microsoft Excel spreadsheets using publicly available KC-X program data are used to compare the USAF's color rating method and weighted sum method, which is a multi-criteria decision making tool. It is presented that if the USAF had used the weighted sum method as its evaluation method, the winner of the KC-X program could have been different. The findings prove that the color rating method is not capable of reflecting small differences and information technology tools can help decision makers choose the best value offeror with less subjectivity.

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USE OF INFORMATION TECHNOLOGY TOOLS IN SOURCE SELECTION DECISION MAKING: A STUDY ON USAF'S KC-X TANKER REPLACEMENT PROGRAM

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requirements for the degree of

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ABSTRACT

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I. INTRODUCTION

The source selection phase of government acquisitions involves many interrelated tasks. At the beginning, teams of experts determine the evaluation factors and significant subfactors that represent the key concerns of the procurement and incorporate those factors into a formal document which is called a Request for Proposal (RFP). Once proposals are received, experts evaluate each proposal against the standards provided in the RFP. If negotiated contracting is the selected method for the acquisition, contractors are allowed to revise their offers and discussions are conducted before the contract is awarded. Otherwise, evaluations are conducted without negotiations and the contract is awarded directly by the Source Selection Authority (SSA) based on the evaluations.[1]

Even though objective factors and subfactors are used in the source selection phase, subjectivity is inevitable in government contracting. While the Federal Acquisition Regulation (FAR) does not provide any clear guidance on evaluating proposals, the source selection decision is usually made based on some evaluations "conducted using any rating method or a combination of methods, including color or adjectival ratings, numerical weights, and ordinal rankings."[2] Besides, proposals are evaluated by different personnel and conclusions may differ significantly, even for the same factor.[3] Therefore, considering the high complexity in the nature of government acquisitions, comparison of proposals and the source selection decision involve subjective judgmental evaluations, and these evaluations may be in conflict with fairness and the best value.[4]

Considering the fact that resources available to governments are becoming scarcer, subjectivity should be reduced as much as possible in contracting, and agencies should find some ways to get the best value from any procurement.

[1] Carl R. Templin and Ken R. Noffsinger, "An Assessment of the Role of Technical and Evaluation Factors," *International Journal of Purchasing and Materials Management* 30 (1994); 38.

[2] Federal Acquisition Regulation (FAR) 15.305.

[3] John Cibinic and Ralph C. Nash, *Formation of Government Contracts*, 3rd ed. (Washington, DC: The George Washington University, 1998), 821.

[4] Templin and Noffsinger, "An Assessment," 38.

As a solution to the problems stated above, quantitative methods and information technology tools can be utilized to augment objectivity in the source selection decision making. Quantitative methods and information technology tools can assist with decision-making by analyzing data and providing some solutions. Choosing an optimal solution among different alternatives using many evaluation criteria, performing risk assessments, and planning complicated operations are some advantages of information technology tools. "Implementation and use of these tools in a systematic method can help shift government purchasing from a tactical, reactive mode of operation to a more strategic, proactive mode of operation."[5]

In this context, the aim of this study is to show the effects of the subjectivity involved in the government procurement processes and suggest some possible solutions. The authors develop and analyze multiple versions of numerical models based on the weighted sum method, which is one of the tools that can be used to solve multi-criteria decision making problems. These models are built in Microsoft Excel using data from a current procurement program.

In this study, the USAF's KC-X Tanker Replacement Program has been selected as the program to be used to frame the research questions. There are some specific reasons for choosing that program. First of all, an Air Force procurement program in which color ratings were used has been chosen to show the effects of subjectivity in government contracting because, in the authors' perspective, the Air Force's color rating method is one of the methods that is incapable of considering small differences between proposals and thus causes subjectivity to play a role during the decision process. In addition, a popular and a current program like the USAF's KC-X program has been selected to be able to reach lots of different comments from many different viewpoints. Considering the confidentiality issues of past procurement programs that make it impossible to reach enough information, a current program provides much more publicly available information. After all these considerations, the authors came up with the idea of doing their study on the USAF's KC-X program.

[5] Kathy L. Spainhower, "An Exploratory Study on the Strategic Use of Information Technology," (master's thesis, Air Force Institute of Technology, 1998), 7.

After doing some research about the KC-X program, it has been discovered that the two different proposals offered very different specifications and capabilities for the same program. This showed the difference between the two offerors' viewpoints and made it clear that this program might be a good sample for this study because of the potential effects of subjectivity.

Another factor that makes this choice even more interesting is the high likelihood of the contract award being protested. Experts of the defense industry were expecting a protest regardless of the winner. Since the proposed KC-X alternatives have very different strengths in capabilities, the results would not easily satisfy the offeror that loses the program award. As expected, after the authors started working on the KC-X program to show the subjectivity involved in source selection (mostly because of the color rating technique) and its effects on the source selection decision, the program was awarded to the Northrop Grumman-Airbus EADS team and Boeing immediately protested the program to the Government Accountability Office (GAO).

In this study, detailed explanations about government contracting and decision-making support techniques are presented first to provide readers with some background information. After that, the USAF's KC-X Tanker Replacement Program is examined in detail to demonstrate its special features and high importance. Also, this part provides the color rating data of both offerors that were found in publicly available sources and used in the models. After these explanatory chapters, the model construction chapter shows how the two versions of the model were built with some simple examples. In the chapter that discusses the analysis and results, it is shown with both versions of the model that the final source selection result of the KC-X Tanker Replacement Program could have been different if the USAF had used the weighted sum method as its source selection evaluation method. Then, optimization is built into the models to perform sensitivity analysis with respect to choices that were made when constructing the models. In the final part, the conclusions from each part of the study are summarized and recommendations for further research are presented to the readers.

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II. ACQUISITION OVERVIEW

A. INTRODUCTION

Government acquisitions are to be conducted in compliance with many laws and regulations that require contracting agencies to ensure that all contractors are treated in an equal manner and that the government acquires the supplies or services for a fair and reasonable price.[6]

In awarding U.S. government contracts, The Competition in Contract Act of 1984 (CICA) requires 'full and open competition' to be provided by contracting officers. According to CICA, "full and open competition means that all responsible sources are permitted to submit sealed bids or competitive proposals on the procurement."[7] The importance of full and open competition for government is that if performed ideally, it results in quality services and products provided to the government at desirable costs. It has been experienced that, on average, 25% of the total cost can be saved by using competitive processes.[8]

The source selection phase in government contracting involves multi-criteria decision making that has to deal with many critical factors, such as cost, technical capabilities, and past performance of contractors. The contracting processes used in government acquisitions have been built to respond to various government procurement needs by evaluating these factors.

Under some requirements, contracting officers may use contracting procedures that provide no full and open competition and the justifications for awarding a contract without competition is stated in Federal Acquisition Regulation (FAR) 6.303. Based on

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[6] Templin and Noffsinger, "An Assessment," 38.

[7] William Thybony, *Government Contracting Based on the Acquisition Regulation (and the Competition in Contracting Act of 1984)* (Thybony, Inc., 1985), 95.

[8] Ibid., 99.

the circumstances, "such procurements may be made on either sole source basis or with limited competition."[9] According to FAR 6.302, situations where full and open competition is not required are as follows:

- "Only one responsible source and no other supplies or services will satisfy agency requirements
- Unusual and compelling urgency
- Industrial mobilization; engineering, developmental, or research capability; or expert services
- International agreement
- Authorized or required by statute
- National security
- Public interest"

This chapter is mainly divided into two parts. The first part (Section B) provides general background information about government contracting. While both methods of government contracting, which are sealed bidding and contracting by negotiations, are explained during this part of the study, the main focus of this paper is on Contracting by Negotiations because it is the technique more commonly used in government contracting practices.

The second part (Section C) provides information about Air Force source selection procedures because the authors are going to use a U.S. Air Force weapon system acquisition, namely the KC-X Tanker Replacement Program, as the study case and example to demonstrate the subjectivity involved in government source selection decisions.

B. CONTRACTING METHODS

Contracting officers are free to choose the method of contracting, but they are required to choose the best responsive method that meets all government requirements.[10] Basically, the complexity of the acquisition and the need for discussion determine the

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[9] Cibinic and Nash, *Formation of Government Contracts*, 280.

[10] Ibid., 312.

methods of contract awarding. For instance, in non-complex acquisitions which do not require discussion, a contract can be awarded to the lowest priced offeror who has proposed to provide at least minimum technical requirements. On the other hand, complex acquisitions, for instance big weapon systems procurements, lead contracting officers to use other options that help to determine the offeror whose proposal would give more value to the government.[11]

In order to accomplish full and open competition, the following competitive procedures are used according to FAR 6.102:

- Sealed bids
- Competitive proposals
- Combination of competitive procedures
- Other competitive procedures

In this study, the first three will be examined while stressing the attributes of only the sealed bidding and the competitive procedures.

1. Sealed Bidding

The purpose of sealed bidding is to encourage competition while avoiding fraud or favoritism.[12] While determining the procedures that will be used for a contract, according to FAR 6.401, contracting officers shall solicit sealed bids if:

- "Time permits the solicitation, submission, and evaluation of sealed bids;
- The award will be made on the basis of price and other price-related factors;
- It is not necessary to conduct discussions with the responding offerors about their bids,
- There is a reasonable expectation of receiving more than one sealed bid."

[11] Spainhower, "An Exploratory Study," 14.

[12] Noel W. Keyes, *Government Contracts under the Federal Acquisition Regulation* (St. Paul, MN: West Publishing Co., 1986), 153.

In sealed bidding, price and price-related factors play a great role in choosing the offeror. According to FAR 14.103-2, “an award is made to the responsible bidder whose bid is responsive to the terms of the invitation for bids and is most advantageous to the government, considering only price and the price related factors included in the invitation.”

The price-related factors in FAR 14.201-8 include:

- “Foreseeable costs or delays to the government resulting from such factors as differences in inspection, locations of supplies, and transportation.
- Changes made, or requested by the bidder, in any of the provisions of the invitation for bids.
- Advantages or disadvantages to the government that might result from making more than one award.
- Federal, state, and local taxes.
- Origin of supplies, and, if foreign, the application of the Buy American Act or any other prohibition on foreign purchases.”

The evaluation process becomes more complex when there are more factors to be considered. Multiple items, indefinite quantities, extended performance periods, or price adjustment provisions make this evaluation process more complex and hard to manage. Additionally, decision making turns to its most difficult form when price-related factors are included in the evaluation formula.[13] In solicitation, the contracting agency must provide all price-related factors and evaluation methods in a clear manner so that all bidders can easily understand how their proposals will be evaluated.[14]

When two or more bids are equal after the evaluation, the contracting agency shall award the contract based on the following order of priority:

- “Small business concerns that are also labor surplus area concerns,
- Other small business concerns,
- Other business concerns that are also labor surplus area concerns,
- Other business concerns.”[15]

[13] Cibinic and Nash, *Formation of Government Contracts*, 593.

[14] Ibid., 614.

[15] Thybony, *Government Contracting*, 147.

If there are still equal bids after going through these priority steps, the contract is awarded by a drawing witnessed by bidding contractors if possible.[16]

2. Contracting by Negotiation

Negotiated contracting includes discussions with contractors and it usually gives an opportunity to contractors to revise their offers before the contract is awarded. According to FAR 15.302, "the objective of source selection in negotiated contracting is to select the proposal that represents the best value." Best value basically means the greatest benefit that the government can get from an acquisition.

In order to get more value through flexibility obtained by negotiations, statutory changes require discussions while awarding a contract, more detailed information about factor and subfactors in solicitations, limitations of competitive range, and detailed debriefings of offerors. Also, CICA orders competitive procedures or a combination of procedures, whichever are suitable, to be used.[17]

In FAR 15.002, in order to get the benefits of the flexibility of negotiation, types of negotiation, which are competitive and sole source acquisitions, are described in a way that aims to reduce complexity due to complicated solicitations that involve unnecessary large numbers of evaluation factors and subfactors.[18]

Contracting agencies can use any process or a combination of processes to get the best value from procurement. These processes basically involve "trade-off" and "lowest price technically acceptable source selection."[19]

The more detailed background information about contracting by negotiation provided after this point will be divided into three sublevels, which are: selection processes, evaluation factors and subfactors and their relative importance, and evaluation of factors.

[16] Thybony, *Government Contracting*, 148.

[17] Ibid., 313.

[18] Cibinic and Nash, *Formation of Government Contracts*, 710.

[19] FAR 15.101.

a. Selection Processes

Before soliciting proposals, contracting agencies shall determine the strategy that will be followed to make the source selection decision. The strategy that is used by agencies is also called "decisional rule."[20]

A solicitation, at least, should state that "evaluation factors other than cost or price, when combined, are-

- significantly more important than cost or price,
- approximately equal in importance to cost or price; or
- significantly less important than cost or price."[21]

The expected outcome of any strategy is to give the government the best value from any procurement. Best value is the greatest benefit that can be obtained in response to the requirement.

In FAR 15.101, "best value" is explained as follows:

> An agency can obtain best value in negotiated acquisitions by using any one or a combination of source selection approaches. In different types of acquisitions, the relative importance of cost or price may vary. For example, in acquisitions where the requirement is clearly definable and the risk of unsuccessful contract performance is minimal, cost or price may play a dominant role in source selection. The less definitive the requirement, the more development work required, or the greater the performance risk, the more technical or past performance considerations may play a dominant role in source selection.

(1) Trade-off Process. Contracting by negotiation allows contracting agencies to make trade-offs between cost and other factors.[22] This process aims to find the best value proposal by comparing the differences between technical specifications and costs and to justify paying more than the lowest price. Therefore,

[20] Cibinic and Nash, *Formation of Government Contracts*, 712.

[21] Ibid.

[22] Ibid., 710.

contracting agencies may not always select the lowest-priced bidder. A contract may be awarded to a higher-priced bidder if the justification is that of better quality of the proposed product or service.[23]

This is explained in FAR 15.101-1 as follows:

> (a) "A tradeoff process is appropriate when it may be in the best interest of the Government to consider award to other than the lowest priced offeror or other than the highest technically rated offeror.
>
> (c) This process permits tradeoffs among cost or price and non-cost factors and allows the Government to accept other than the lowest priced proposal. The perceived benefits of the higher priced proposal shall merit the additional cost, and the rationale for tradeoffs must be documented."

(2) Lowest Price Technically Acceptable Source Selection Process. In this process, the best value concept is accomplished when the strategy is chosen, not after or during evaluation of the proposals.[24] In other words, it is certain that the offeror that proposes a technically acceptable product or service with the lowest price gives the possible best value to the government in this process. FAR 15.101-2 describes the process as follows:

> (a) The lowest price technically acceptable source selection process is appropriate when best value is expected to result from selection of the technically acceptable proposal with the lowest evaluated price.

When evaluating proposals that meet or exceed requirements for non-cost factors based on price, non-cost factors have equal importance. Therefore, if a proposal does not meet any of the non-cost factors, the offeror with that deficient proposed product or service loses the contract.[25]

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[23] John R. Trumm, *A Decision Analysis Tool for the Source Selection Process* (Air Force Institute of Technology, 2006), 18.

[24] Cibinic and Nash, *Formation of Government Contracts*, 715.

[25] Ibid., 716.

(3) Combination of Trade-off and Low Price Acceptable Processes. Although FAR does not provide any explanation in regards to combined processes, in part 15.101 it allows them to be used. In this process, while some factors are evaluated based on a "go, no-go" basis, others are evaluated on their relative values. Otherwise, as another strategy, first all factors are evaluated based on a "go, no-go" basis and the proposals that can pass this first step are evaluated on their relative merit.[26]

b. Evaluation Factors and Subfactors and Their Relative Importance

Evaluation factors and subfactors are milestones in a contract that describe what is significant for the procurement needs. These factors and their relative importance should be clearly described in solicitation to be completely understood by offerors.

According to FAR 15.304, "these factors and subfactors must

- represent the key areas of importance and emphasis to be considered in the source selection decision; and
- support meaningful comparison and discrimination between and among competing proposals."

According to FAR 15.304, contracting officers are free to choose these factors and determine their relative importance. However, there are some requirements to be followed related to these factors:

- In all government contracts, cost should be evaluated.
- One or more non-cost factors should be evaluated to ensure the quality of products or services.
- Past performance shall be evaluated unless the contracting officer documents that it is not an appropriate evaluation factor.

The relative importance of the evaluation factors should be stated in two steps in the request for proposal (RFP). In the first step, the relationship of cost/price to the non-price factors should be pointed out and then, as a second step, the relative importance of the factors and subfactors in the non-cost or price areas should be described.

[26] Cibinic and Nash, *Formation of Government Contracts*, 718.

(1) Relationship of Cost/Price to Other Factors. An RFP should, at least, involve a statement indicating the decisional logic that will be used to make the source selection decision. It is essential for establishing competition to inform each offeror whether the award will be made based on the lowest-price acceptable proposal basis or trade-off basis. [27]

Variable relationships and fixed relationships can be used to determine the importance of the factors. A variable relationship is usually preferred when the cost to government will vary depending on the other factors. Also, variable relationships among other factors are possible. [28]

(2) Relative Importance of Other Factors. There are a lot of different methods to determine the relative importance of factors other than cost or price.

One of the simplest ways to disclose the relative importance of factors is to list the factors that will be used in the evaluation. With this method, no explanation of differences between factors is provided and the offerors may assume that all evaluation factors have approximately equal importance in determining the winning proposal.[29]

Another way to indicate the relative importance is to list the factors in descending order based on their importance without assigning a weight to each of them. This method is useful when there is "a reasonable downward progression of evaluation weights."[30] On the other hand, this method is satisfactory when the difference in the importance of two factors following one another is small. Besides, if a factor has more importance compared to others, this should be disclosed in the RFP.[31]

[27] Cibinic and Nash, *Formation of Government Contracts*, 748.

[28] Ibid.

[29] Ibid., 751.

[30] Ibid.

[31] Ibid.

c. Evaluation of Factors and Subfactors

According to FAR 15.305, "evaluations may be conducted using any rating method or combination of methods, including color or adjectival ratings, numerical weights, and ordinal rankings."

Additionally, DoD Directive 4105.62 states:

> There is no prescribed methodology for rating. Past practices include color coding, numerical, and plus or minus checks. The important thing is not the rating methodology but the consistency with which it is applied to elements of proposals and among proposals to ensure a though and fair evaluation. Evaluators must be well rounded in their field of expertise and be able to apply mature professional judgment….evaluators must support the rating assigned with a concise narrative that addresses strengths, weaknesses, and risks in the proposal.[32]

As advised by these regulations, contracting agencies can use words or symbols to describe the compatibility levels of each evaluation factor and this method is called adjectival ranking. For instance, the Air Force uses a descriptive adjective system, a color coding system, and a symbol system.[33] Since the Air Force source selection rating system is one the most significant cornerstones in this study, more focus will be given to it and explanations about it will be provided throughout the study.

Another method for evaluating the factors is to use numeric point scores or percentages for each of them. This method may be a good guide for source selection authorities while selecting the best offeror, but it is warned that it should not be used as a primary tool in the decision-making process. It is stated that:

> Numerical point scores, when used for proposal evaluation, are useful as guides to intelligent decision making, but are not themselves controlling in determining award, since these scores can only reflect the disparate, subjective, and objective judgments of the evaluators. Whether a given point spread between competing offers indicates the significant superiority of one proposal over another depends on the facts and circumstances of

[32] Spainhower, "An Exploratory Study," 22.

[33] Ibid.

> each procurement, and while technical scores must of course be considered by Source Selection Authorities (SSAs), such officials are not bound thereby.[34]

Table 1 below shows a combination of adjectival and numerical systems:[35]

Numerical Scores	**Adjective Rating**	**Definition / Evaluation**
10	Excellent	Innovative, comprehensive and complete in all details, meets all requirements and objectives without "gold plating"
9	Very Good	Substantial response in clearly definable detail, meets all critical requirements
7	Average	Generally meets minimum requirements
6	Poor	Lack of essential information to substantiate data presented
5	Unsatisfactory	Lack of understanding of requirements or omissions in major areas
0	No data	

Table 1. Sample Cross Reference of Numerical and Adjectival Scoring Systems.

C. SOURCE SELECTION IN UNITED STATES AIR FORCE

The objective of source selection in the U.S. Air Force is to select the offeror which proposes the best value to the government. In major weapon system procurements, the Air Force uses contracting by negotiation procedures to encourage discussions and negotiations to reach the best value. The confidence in an offeror's ability to meet all

[34] Spainhower, "An Exploratory Study," 23.

[35] Ibid.

requirements perfectly is the key in a best value continuum, and this confidence may lead SSA to award a contract to an offeror which is not the one offering the lowest cost to the government. On the other hand, openness and early industry participation are the main points associated with the relations with industry in the acquisitions of the Air Force.[36]

1. Categories of Air Force Acquisitions

There are three categories of Air Force source selection based on the dollar value and complexity of the acquisition. The categories are as follows:

- Basic source selection
- Median source selection
- Agency source selection

Basic source selection is the easiest one among all three types and the associated procedures are simple, direct and minimal. For non-information technology negotiated acquisitions, the threshold is $10 million and for information technology efforts, the cost range should be less than $15 million per one year and less than $30 million for the whole program.[37]

Median source selection is used for moderately complex source selections and needs a more structured approach than basic source selections. Cost/price, past performance, mission capability, and proposal risk are always used as factors in this type of source selection. For non-information technology negotiated acquisitions, the minimum threshold is $10 million and the maximum threshold is $100 million. On the other hand, for information technology efforts, "these procedures apply to Non-Major Automated Information Systems (MAIS) that are equal to or greater than $15 million in a fiscal year or are equal to or greater than $30 million for the total program but less than $120 million."[38]

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[36] Air Force Source Selection Procedures Guide, 3, https://www.afmc-mil.wpafb.af.mil/HQ-AFMC/PK/pkp/polvault/guides/sspguide.doc (accessed December 20, 2007).

[37] Ibid., 5.

[38] Ibid., 6.

Agency source selection procedures are used for the most complex acquisitions that need a more structured approach than median source selections. Under the mission capability factor, there are several subfactors and elements to be evaluated if necessary. For non-information technology negotiated acquisitions, the minimum threshold is $100 million. For information technology acquisitions, the minimum threshold is $120 million to use agency source selection procedures.[39]

2. Steps in Air Force Source Selection

All these three types of source selection procedures are composed of the same three steps, which are:

1. Pre-Solicitation activities
2. Evaluation activities
3. Award activities

In this study, because the authors are going to use a major weapon system acquisition as an example, the cost of which exceeds billions of dollars, the agency source selection procedure will be the focus of discussion.

a. Pre-Solicitation Activities

After determining the requirements, early participation of the industry and use of oral presentations instead of written statements are recommended in this stage of source selection. The other significant activity is to identify high-risk areas and determine discriminators for the selection. Determining these important factors makes it possible to build the basis for award, evaluation criteria, and evaluation factors which are announced in the source selection plan.

(1) Evaluation Factors. The following four factors are used in Air Force source selection procedures:

- Mission capability
- Proposal risk

[39] Air Force Source Selection Procedures Guide, 7.

- Past performance
- Price or cost evaluation factor

The mission capability factor focuses on the technical requirements that have significant value in the source selection decision. If subfactors under this factor are to be used, the number of subfactors can not exceed six.[40] The need for using subfactors and elements are determined by performing a formal risk assessment. Keeping the numbers of subfactors and elements low helps the evaluation team make a meaningful and complete evaluation. [41]

The proposal risk factor focuses on the risks an offeror puts on the program's significant goals, which are cost, schedule and performance. This factor is not mandatory for acquisitions of $10 million or below.[42]

The past performance factor focuses on the confidence that an offeror provides to the government showing the offeror's ability to supply products or services while meeting all requirements stated in the solicitation. It may be the most important factor or at least as important as the most important non-cost factor in the evaluation.[43] No subfactor is typically assigned to this factor like the price/cost factor.[44]

Price/cost evaluation focuses only on reasonableness and realism aspects of the price/cost proposed by an offeror. Therefore, the data requested from an offeror to perform this evaluation should be limited to the amount required to perform the reasonableness and realism assessment.[45]

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[40] Air Force Mandatory Source Selection Procedures 4.4.1.1, http://farsite.hill.af.mil/reghtml/regs/far2afmcfars/af_afmc/affars/5315.htm#P41_1723 (accessed January 14, 2007).

[41] Air Force Source Selection Procedures Guide, 43.

[42] Air Force Mandatory Source Selection Procedures 4.4.1.2.

[43] Air Force Source Selection Procedures Guide, 42.

[44] Alexander R. Slate, "Best Value Source Selection: The Air Force Approach, Part 1," *Defense AT&L* (September-October 2004); 52.

[45] Air Force Source Selection Procedures Guide, 43.

After determining all factors, subfactors, and elements, as well as their relative importance, a formal request for proposal is issued and released.

b. Evaluation Factor Assessment Activities

The goal of source selection evaluation in Air Force acquisitions is to provide the best value to the government. Proposals given by offerors can only be evaluated based on the factors, subfactors and elements, if applicable, included in the RFP.

(1) Mission Capability Assessment. The mission capability assessment focuses on the deficiencies and strengths in the offeror's proposal. If there are subfactors established under this factor, they should be rated at a subfactor level and an overall factor rating is not assigned. This factor is rated using colors and each of the mission capability subfactors should get a color coding based on the performance capability an offeror proposes.[46] Table 2 depicts the color ratings and their descriptions used in this evaluation.

MISSION CAPABILITY COLOR RATINGS		
Color	**Rating**	**Description**
Blue	Exceptional	Exceeds specified minimum performance or capability requirements in a way beneficial to the government; proposal must have one or more strengths and no deficiencies to receive a blue rating.
Green	Acceptable	Meets specified minimum performance or capability requirements delineated in the RFP; proposal rated green must have no deficiencies but may have one or more strengths.
Yellow	Marginal	Does not clearly meet some specified minimum performance or capability requirements delineated in the RFP, but any such uncertainty is correctable.

46 Air Force Mandatory Source Selection Procedures 5.5.1.

Red	Unacceptable	Fails to meet specified minimum performance or capability requirements; proposal has one or more deficiencies. Proposals with an unacceptable rating are not awardable.

Table 2. Mission Capability Color Ratings.

A yellow/marginal rating should be eliminated through information exchanges and at the end of the final evaluation, it should be rare.[47] If a red rating remains, that proposal can not be awarded the contract.

Along with color ratings, SSA should be informed with narrative assessments, and those assessments should not compare offerors, they should only evaluate each offeror's proposal against requirements established in the RFP.[48]

(2) Proposal Risk Assessment. Proposal risk assessment focuses on the weaknesses in the proposed approach. It should be evaluated and rated at the subfactor level against the mission capability subfactors, and an overall rating is not assigned.49 Table 3 demonstrates the ratings used in this evaluation.

PROPOSAL RISK RATINGS	
Rating	**Description**
High	Likely to cause significant disruption of schedule, increased cost, or degradation of performance. Risk may be unacceptable even with special contractor emphasis and close government monitoring.
Moderate	Can potentially cause disruption of schedule, increased cost, or degradation of performance. Special contractor emphasis and close government monitoring will likely be able to overcome any difficulties.
Low	Has little potential to cause disruption of schedule, increased cost, or degradation of performance. Normal contractor effort and normal government monitoring will likely be able to overcome any difficulties.

Table 3. Proposal Risk Ratings.

[47] Air Force Mandatory Source Selection Procedures 5.5.1.

[48] Air Force Source Selection Procedures Guide, 46.

[49] Air Force Mandatory Source Selection Procedures 5.5.2.

(3) Past Performance Assessment. Past performance evaluation demonstrates the government's confidence in an offeror's ability to meet all requirements established in the RFP. The most critical aspects of the information obtained about the offeror's past performance are recency and relevancy. In agency source selection, past performance should be evaluated by a Performance Risk Assessment Group (PRAG).[50]

A confidence rating is assigned to each offeror to assess recent past performance, with focus on the performance related to the mission capability subfactors and cost or price.[51] The six confidence assessment ratings are seen in Table 4.

PERFORMANCE CONFIDENCE ASSESSMENTS	
Rating	**Description**
High Confidence	Based on the offeror's performance record, the government has high confidence the offeror will successfully perform with the required effort.
Significant Confidence	Based on the offeror's performance record, the government has significant confidence the offeror will successfully perform with the required effort.
Satisfactory Confidence	Based on the offeror's performance record, the government has confidence the offeror will successfully perform the required effort. Normal contractor emphasis should preclude any problems.
Unknown Confidence	No performance record is identifiable.
Little Confidence	Based on the offeror's performance record, substantial doubt exists that the offeror will successfully perform the required effort.
No Confidence	Based on the offeror's performance record, extreme doubt exists that the offeror will successfully perform the required effort.

Table 4. Performance Confidence Assessments.

(4) Cost/Price Assessment. Cost/price assessment focuses on the fairness and realism of the cost/price data provided. A risk rating should be assigned to this factor to assess the risk involved to the proposed cost. Table 5 depicts the ratings used in the cost/price risk assessment.

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[50] Air Force Source Selection Procedures Guide, 45.

[51] Air Force Mandatory Source Selection Procedures 5.5.3.

COST/PRICE RISK RATINGS	
Rating	**Description**
High	Likely to cause significant disruption of schedule, increased cost, or degradation of performance. Risk may be unacceptable even with special contractor emphasis and close government monitoring.
Moderate	Can potentially cause disruption of schedule, increased cost, or degradation of performance. Special contractor emphasis and close government monitoring will likely be able to overcome any difficulties.
Low	Has little potential to cause disruption of schedule, increased cost, or degradation of performance. Normal contractor effort and normal government monitoring will likely be able to overcome any difficulties.

Table 5. Cost/Price Risk Ratings.

Before awarding the contract, it may be necessary to exchange some information with offerors, and these information exchanges are composed of "clarifications", "communications", and "discussions." After finishing these activities, final proposals are evaluated by the evaluation team.

c. Award Activities

After proposals are received, an evaluation team that consists of many experts performs a very detailed assessment and reaches the final color/adjectival ratings and narrative assessments for each offer. Before SSA makes the source selection decision, the evaluation team gives him a briefing containing all these assessments. This briefing includes the strengths, deficiencies, and weaknesses an offeror has in its proposal as the narrative assessments. The SSA evaluates all color/adjectival ratings and narrative assessments provided by the evaluation team and awards the contract to the offeror that proposes the best value to the government.[52]

After announcing the results and the winner, a debriefing that provides all evaluations with required explanations is presented to each offeror.53

[52] Air Force Source Selection Procedures Guide, 49.

[53] Ibid., 50.

D. SUMMARY

In this chapter, a general overview of acquisition processes is provided. First, contracting methods are discussed and then evaluation and selection processes are defined briefly. In the second part of this chapter, because this project will focus on Air Force's color rating method, Air Force source selection is examined in greater detail in terms of categories of Air Force acquisitions, steps in Air Force source selection, evaluation activities, and award activities. The next chapter will discuss the decision-making support techniques that allow a final assessment to be reached from the individual assessments explained in this chapter.

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III. DECISION MAKING SUPPORT TECHNIQUES OVERVIEW

A. INTRODUCTION

Decision makers are trying to make more accurate decisions and their only assets in doing so are their personal experience and the available information about the situation. For accurate decisions, decision makers need relevant and correct information, and they need to analyze it correctly to come up with a beneficial final decision. With the help of information technology, which brings a lot of support techniques to help them make better analysis, decision makers can make better decisions.

In this part of the authors' study, they will give some background information about the available techniques to solve a multi-criteria problem because the example study case (the Air Force's KC-X program) in this thesis is a major weapon system procurement and has more than one criterion to consider while trying to come up with the best value product for the government. In general, decision makers have two different choices to use to solve multi-criteria problems. A decision maker can decide on using a multi-objective optimization or a multi-criteria decision making technique. Under multi-criteria decision making, there are many different techniques available, but the authors choose the most popular eight methods to provide background information about. Also, there are many decision support software programs in the literature. These software programs are supporting tools that use one or some of the techniques, but the decision maker does not need to know anything about the techniques to use these programs. The authors will talk about two of them that best fit their needs. The authors will give a brief summary of each technique and as a conclusion they will make the determination about what technique they will use in their study. However, the aim of this chapter is not to provide guidance about choosing the appropriate technique where it supports the most accurate results for that special condition. Also, in the literature of techniques, it was stated that there are different conditions which make one of the techniques the most appropriate for that condition. Most of the literature studies do not provide the conditions that make the techniques the most appropriate ones for that specific condition.

B. OVERVIEW

There are some different alternative techniques to help and support decision makers when they need to make a decision in real-life situations. Real-life situations consist of multiple criteria which often conflict with each other. In a multiple criteria decision making environment, there are two main options of techniques to choose from for a decision maker. A decision maker can choose any of the techniques under the multi-criteria decision-making umbrella or any of the optimization techniques, or otherwise any of the software under the decision support system or expert systems umbrella can be chosen to support the decision whenever a decision maker does not want to use any of the techniques.

The chart below in Figure 1 is the summary of options under a hierarchical order for a decision maker to support his or her decisions for multi-criteria situations.

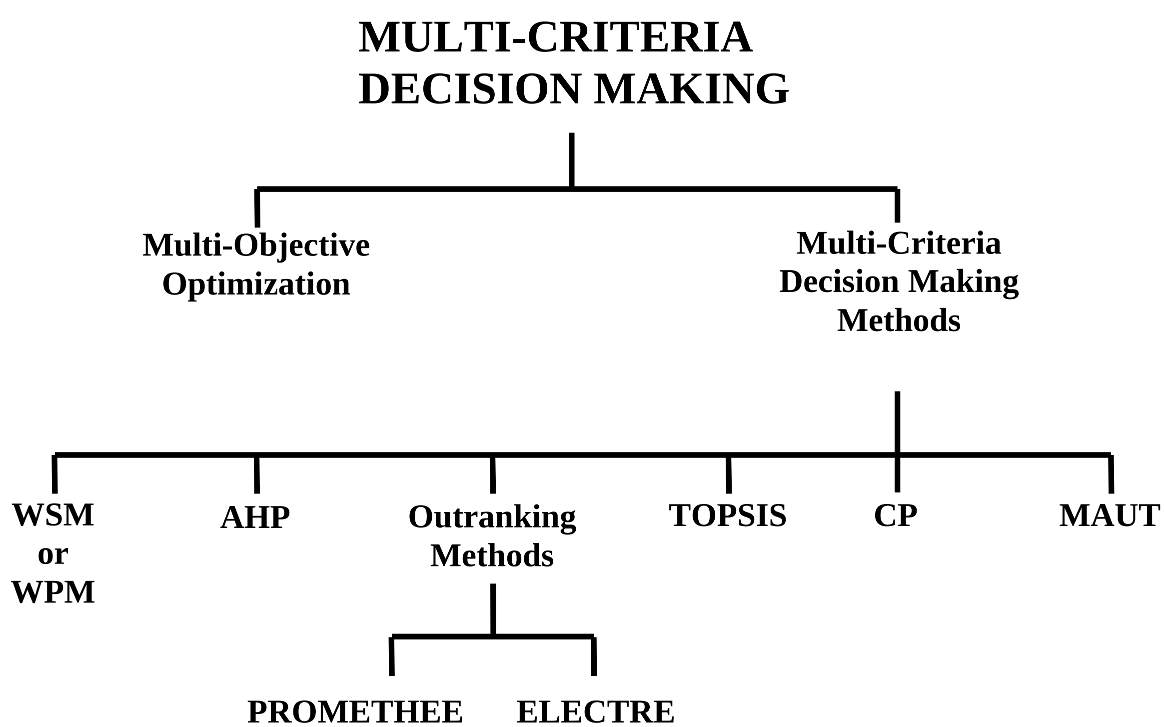

Figure 1. Hierarchical Order for Multi-criteria Decision Making.

1. Multi-Objective Optimization

The basic constrained single objective optimization problem is formulated as follows:

$$
\begin{array}{ll}
\text{Min} & J = f\left(X\right) \\
\text{s.t.} & \begin{array}{l} h(X) = 0 \\ g(X) \le 0 \end{array} \\
\text{D.V.} & X_L \le X \le X_U
\end{array}
$$

where J is the objective function and J equals to a real valued function $f(X)$, X is a vector of n real independent variables called decision variables, $h(X)$ and $g(X)$ are representing the feasible set for X (h represents the set of equality constraint functions and g represents the set of inequality constraint functions of X), and $X_L<=X<=X_U$ represents the lower and upper simple boundaries on feasible values of X.

There are several different methods which can be used for solving optimization problems like the simplex method for linear constrained problems, sequential quadratic programming (SQP) for nonlinear constrained problems, and branch-and-bound techniques for discrete variables depending on the types of objectives, constraints and variables.[54]

However, real-world applications often imply multiple objectives. For example, in product-design optimization, the cost and the quality of products are two conflicting objectives.[55] Another example from real engineering design decisions typically involve both technical (i.e., maximize performance) and economic (i.e., minimize cost) considerations at the same time. In general, performance and cost are also opposing objectives, like quality and cost, and performance can only be increased by increasing cost. In these cases, the optimization problem becomes multi-objective.[56]

[54] Robert A. Wolf, "Multi-Objective Collaborative Optimization of Systems of Systems," (master's thesis, Massachusetts Institute of Technology, 2005), 24.

[55] Dirk Buche, Peter Stoll, and Petros Koumoutsakos, "An Evolutionary Algorithm for Multi-Objective Optimization of Combustion Processes," *Center for Turbulence Research Annual Research Briefs* (2001); 231, http://ctr.stanford.edu/ResBriefs01/bueche.pdf (accessed December 25, 2007).

[56] Wolf, "Multi-Objective Collaborative," 24.

The typical multi-objective formulation is given as follows:

$$\begin{array}{ll} \text{Min} & J = f(X) = \left[f_1(X), f_2(X), \ldots, f_n(X) \right] \\ \text{s.t.} & h(X) = 0 \\ & g(X) \leq 0 \\ \text{D.V.} & X_L \leq X \leq X_U \end{array}$$

where J and equally *f(X)* is a function (vector) of n different objective functions at solution X. The solution to the multi-objective optimization problem is a set of Pareto points. Pareto solutions are those for which improvement in one objective can only occur with the worsening of at least one other objective. Thus, instead of a unique solution to the problem as in a single objective optimization, the solution to a multi-objective problem is a set of Pareto points. While working on multiple objectives, generally a single solution that optimizes all objectives simultaneously does not exist. There are multiple solutions that are "optimal" with respect to the different objective functions. Generally, the best solutions are the ones that represent a compromise between the various objectives.[57]

As a multi-objective problem creates multiple solutions, in order to come up with a single preferred solution, some method must be chosen to decide the best compromise which maximizes the utility function below. With this equation, multiple objective values can be combined into a single utility.

$$u\left[f(X) \right] = u\left[f_1(X), f_2(X), \ldots, f_n(X) \right]$$

The methods to reach a single preferred solution can be divided into four primary classes:[58]

- No preference methods (the distance to the ideal point is minimized-no input from decision maker)
- A priori methods (decision makers define the utility function before any analysis)

57 Wolf, "Multi-Objective Collaborative," 25.

58 Ibid.

- Iterative methods (identify decision maker preferences progressively as the design analysis progresses)
- Posterior methods (identify the Pareto-optimal frontier and then allow the decision maker to determine the best compromise solution)

2. Multi-Criteria Decision Making (MCDM) Methods

Multi-criteria decision making is a well-known part of the decision making process and is an important part of the subject of operations research when dealing with more than one decision criteria to make a decision. Conflicts and incomparability (because of not being measurable) of some criteria are the problems that these techniques are mostly facing. There are several different methods under MCDM's umbrella. Each method has its own characteristics and, therefore, each method can be the best method when the conditions suit its characteristics. However, in this study, as stated before, the aim is not to provide guidance for picking up the best technique for that special occasion (condition) or a list of best occasions for each technique. Likewise, most of the literature studies reviewed by the authors simply provide reasons why they think that the technique they choose fits the best for them.

a. Weighted Sum Method (WSM) and Weighted Product Method (WPM)

The WSM is one of the most popular and commonly used approaches, especially for single dimensional problems. When there are *M* alternatives and *N* criteria, in this method, the best alternative can be found by the following expression;[59]

$$A^*_{WSM} = Max_{i=1,2,3,\ldots,M}\left[\sum_{j=1}^{N} a_{ij} w_j\right]$$

where A^*_{WSM} is the weighted sum of the best alternative, a_{ij} is the actual value of i^{th} alternative for the j^{th} criterion, and w_j is the weight of relative importance of the j^{th} criterion. The final value of each alternative is equal to the sum of values for each

[59] S. D. Pohekar and M. Ramachandran, "Application of Multi-Criteria Decision Making to Sustainable Energy Planning-A Review," *Renewable and Sustainable Energy Reviews* 8 (2004): 368, http://web.nuu.edu.tw/~ctchen/download/96_1/m/96-05.pdf (accessed December 25, 2007).

criterion. This simple method can have problems when it is used for multi-dimensional problems and there are different units; it is meaningless to try to sum these results in different units.[60]

Since there is more than one criterion and different relative importance for each criterion, weights are used to capture the relative importance of the different criteria to the decision maker. This given relative importance of the criteria provides the model with tradeoffs, and with the help of weights, the model allocates their contribution to the overall score. In a scoring model, the weighted sum of the scores represents the project's overall value (score).

While using this technique, it is necessary to first draw a hierarchy tree of objectives/factors and then start from the bottom level. Factors can have some subfactors and subfactors can have elements. Therefore, an overall score will be calculated for each subfactor group under a factor. Whenever an overall value is gotten from a sublevel, the procedure is started from the beginning for the new level. After getting an overall value (score) for the alternative, the same procedure is implemented for the next alternative. After getting an overall score for each alternative, the best option will be the alternative with the highest score for the decision maker’s preferences.

The weighted sum method, which is also called multi-criteria scoring or the congruence model in different literary sources, is a basic and well-known technique that is used in different subject areas with sometimes different names. As it is used in MCDM (with three different names - weighted sum method, multi-criteria scoring or congruence model), it is also commonly used in economics under 'cost-benefit analysis for measure of effectiveness' calculations. This technique is also used in statistics and mathematics as the weighted average (A method of computing a kind of arithmetic mean of a set of numbers in which some elements of the set carry more importance (weight) than others).[61]

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[60] Pohekar and Ramachandran, “Application of Multi-Criteria Decision Making.”

[61] Cliff T. Ragsdale, *Spreadsheet Modeling and Decision Analysis: A Practical Introduction to Management Science* (Mason: South-Western Learning, 2004), 806.

A very similar method to WSM is the weighted product method (WPM). The main difference between these two methods is that in WSM, one adds the values for each criterion to get the final value, while in WPM, multiplication of these values take place instead of addition. In WPM, each alternative is compared with others by multiplying the ratios created by each criterion. When trying to compare the alternatives by using WPM, one takes A_K and A_L as two of the alternatives and solves the following expression;[62]

$$R\left(A_K / A_L\right) = \sum_{j=1}^{N} \left(a_{kj} / a_{Lj}\right)^{wj}$$

where N shows the number of criteria, a_{kj} and a_{Lj} are the actual value of alternative K and L for the j^{th} criterion, and w_j is the weight of the relative importance of j^{th} criterion. When $R(A_K/A_L)$ is greater than 1, A_K is more preferable than A_L (in maximization problems). The overall best alternative is the one which is more preferable than every other alternative.[63]

b. Analytical Hierarchy Process (AHP)

The analytical hierarchy process (AHP), developed by Thomas L. Saaty at the Wharton Business School, provides a tool to decision makers to analyze decisions hierarchically with the overall goal of the decision at the top of the model, strategic objectives in the higher levels, and sub-objectives with evaluation criteria at the bottom.[64] The hierarchy is fairly simple but the mathematics is a little complex. To start the process, a goal is broken down into objectives and sub-objectives, as shown in Figure 2, until each sub-objective can be defined using one or more measurable criteria.

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[62] Ragsdale, *Spreadsheet Modeling*, 369.

[63] Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 369.

[64] Michael C. Weinlein, "Funding for First Responders from a Threat and Prevention Approach," (master's thesis, Naval Postgraduate School, 2004), 22.

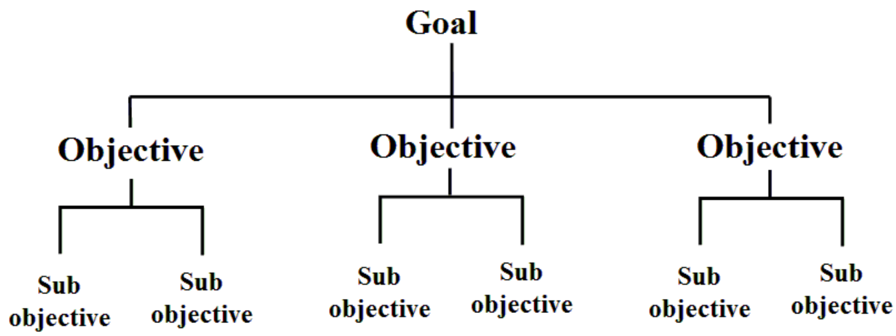

Figure 2. AHP's Hierarchical Approach.

Once the hierarchy is established, weights are assigned to every branch in the tree. To do this, analysis starts at the bottom of the tree. Starting with each sub-objective, the measurable criteria for that sub-objective are compared using a pair-wise comparison method such that each criterion is compared against every other criterion, including itself. This creates a matrix of values that indicates the relative importance of every criterion versus every other criterion under a sub-objective. This matrix

$$A = \begin{pmatrix} a_{11} & a_{12} \cdots & a_{1n} \\ a_{21} & a_{22} \cdots & a_{2n} \\ \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{nn} \end{pmatrix}$$

is created by putting a numerical value resulting from the result of the pair-wise comparison of criterion i with criterion j into the position a_{ji}, and its inverse into position a_{ij}, to obtain all of the pair-wise comparisons performed for a given sub-objective.[65] The values that are used as entries in this matrix, and their verbal descriptions, are given in Table 6.

[65] Weinlein, "Funding for First Responders."

Relative Importance	Definition
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6,8	Intermediate judgment values

Table 6. Fundamental Scale for Pair-Wise Comparisons.

Once the matrix is determined, the values within each column of the matrix are then normalized so the entries within each column sum to one. Then, the values within each row are averaged to achieve a normalized vector of weights for the criteria (the values of this vector sum to one). This vector of weights can now be used to evaluate alternatives by summarizing the criteria values of each alternative into a single number in a similar way as the weighted sum method. This process is repeated for each level of the hierarchy so the evaluation of each alternative can be summarized in a single number for final comparison. The alternative with the highest final value should be taken as the best alternative.

AHP also includes the calculation of an inconsistency index. This allows the decision maker to determine if his or her choices of pair-wise comparison scores are consistent. Whenever these choices are consistent, it means that the final decision is made well.[66] A numerical example of the analytical hierarchy process can be found in Weinlein, pp. 22-24.

c. Outranking Methods

When there are not many alternatives to be evaluated in a complex problem, which has many criteria to be considered and many participants involved, outranking methods can be used by decision makers.

[66] Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 369.

If the following two conditions are met, it is defined that the action a_k outranks the action a_l:

- "a_k is at least as good as a_l with respect to a major subset of the criteria,
- a_k is not too bad relative to a_l with respect to the remaining criteria."[67]

The outranking methods demonstrate the dominance of one alternative over another by using ordinal and descriptive information. An important feature they have is that they provide limited preference ranking, not a full ranking. They do not require a certain utility function that shows the exact preference structure of decision makers. They just need enough information to indicate that one alternative is better than the other one.[68]

There are two phases in every outranking method:

- "The construction of an outranking relation,
- The exploitation of this relation in order to assist the decision-maker."[69]

The most common outranking methods are the preference ranking organization method for enrichment evaluation (PROMETHEE) and the elimination and choice translating reality (ELECTRE) method.[70]

Both methods involve a set of alternatives and decision criteria that are used as basis for the evaluations. These criteria can be descriptive or ordinal and may involve uncertainty. The uncertainty in the criteria is handled with a threshold model that involves indifference and preference thresholds. An indifference threshold is the point

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[67] "Multi-criterion decision-making using ELECTRE," University of Geneva, http://ecolu-info.unige.ch/~haurie/mutate/Mutate_final/Lectures/Lect_1_3_2/lect_1_3_2.htm (accessed December 28, 2007).

[68] Annika Kangas, Jyrki Kangas, and Jouni Pykalainen, "Outranking Methods As Tools in Strategic Natural Resources Planning," *Silva Fennica* 35, no. 2 (2001); 216, http://www.metla.fi/silvafennica/full/sf35/sf352215.pdf (accessed December 29, 2007).

[69] J. P. Brans and Ph. Vincke, "A Preference Ranking Organization Method: (The PROMETHEE Method for Multiple Criteria Decision-Making)," *Management Science* 31, no. 6 (1985);. 648, http://links.jstor.org/sici?sici=0025-1909(198506)31%3A6%3C647%3AAPROM(%3E2.0.CO%3B2-B (accessed December 29, 2007).

[70] Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 365.

below which the two alternatives are indifferent to the decision maker and the preference threshold is the point above which an alternative is dominant and preferable over another alternative. Between these two thresholds there is a zone in which the decision maker can not decide and it is called the zone of weak preference. However, in the case where the criteria are ordinal or descriptive, this zone is not taken into consideration.[71]

(1) Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE). This method needs a preference function for each criterion to compute the degree of preference.[72] "The credibility of the outranking relation that alternative a_k is better than alternative a_l is described by the outranking degree and it is calculated as;

$$\prod(a_k, a_l) = \sum_{j=1}^{p} w_j F_j(a_k, a_l)$$

where $F_j(a_k, a_l)$ is the preference function and w_j is the relative importance of the different criteria."[73]

The value of preference functions is calculated using thresholds p_j and q_j as [74]

$$F_j(a_k, a_l) = \left\{ \begin{array}{l} 1, if g_j(a_k) - g_j(a_l) \geq p_j \\ 0, if g_j(a_k) - g_j(a_l) \leq q_j \\ \dfrac{g_j(a_k) - g_j(a_l)}{p_j - q_j}, otherwise \end{array} \right\}$$

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[71] Kangas, Kangas, and Pykalainen, "Outranking Methods," 217.

[72] Jean-Pierre Brans and Bertrand Mareschal, "How to Decide with PROMETHEE," VisualDecision.com. 2, http://www.visualdecision.com/Pdf/How%20to%20use%20PROMETHEE.pdf (accessed December 26, 2007).

[73] Kangas, Kangas, and Pykalainen, "Outranking Methods," 218.

[74] Ibid.

The outranking degree that is calculated using this value of preference function and relative importance is then used to calculate the positive, negative, and net preference flows as shown below:[75]

$$\phi^{+}(a_k) = \sum_{1 \neq k} \prod (a_k, a_l) / (n-1)$$
$$\phi^{-}(a_k) = \sum_{1 \neq k} \prod (a_l, a_k) / (n-1)$$
$$\phi(a_k) = \phi^{+}(a_k) - \phi^{-}(a_k)$$

The positive flow shows how much an alternative is more powerful than the other alternatives while the negative flow shows how much weaker it is.[76] An alternative outranks the other one if its net flow is higher than that of the other one. On the other hand, if their net flows are equal, they are indifferent to the decision maker. Therefore, the alternative that has the highest net flow is considered to be the best choice.[77]

(2) The Elimination and Choice Translating Reality (ELECTRE). When decision criteria are either quantitative or qualitative and not even comparable, this outranking method can be used to order all alternatives.[78] In the ELECTRE method, the concordance and discordance indices as well as the threshold values are used to draw graphs for strong and weak relationships. After that, alternatives are ordered in a repeated process with the assistance of these graphs.[79]

An index of concordance that demonstrates that an alternative is at least as good as another one is calculated for each pair of alternatives. The formula used to compute the concordance index is shown below:

$$C(a_k, a_l) = \sum_{j=1}^{p} w_j c_j (a_k, a_l)$$

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[75] Kangas, Kangas, and Pykalainen, "Outranking Methods."

[76] Brans and Mareschal, "How to Decide with PROMETHEE," 2.

[77] Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 371.

[78] University of Geneva, "Multi-criterion decision-making using ELECTRE."

[79] Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 371.

where $c_j(a_k,a_l)$ is the local concordance index and w_j is the relative importance of the different criteria.[80]

The value of the local concordance index is calculated using thresholds p_j and q_j as[81]

$$F_j\left(a_k,a_l\right)=\begin{cases} 1, if g_j\left(a_k\right)-g_j\left(a_l\right)\geq p_j \\ 0, if g_j\left(a_k\right)-g_j\left(a_l\right)\leq q_j \\ \dfrac{g_j\left(a_k\right)-g_j\left(a_l\right)-q_j}{p_j-q_j}, otherwise \end{cases}$$

As a result, binary outranking relations between the alternatives are provided with this method.[82]

d. The Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS)

TOPSIS was developed as an alternative to ELECTRE by Kwangsun Yoon and Hwang Ching-Lai in 1980. The basic concept of this method is that the most preferred alternative should not only have the shortest distance from the positive ideal solution (the closest to positive ideal), but also have the longest distance from the negative ideal solution (the farthest to negative ideal). This technique has been widely used in various multi-criteria decision making models due to its simplicity and comprehensibility in concept, its computational efficiency, and its ability to measure the relative performance of the decision alternatives in a simple mathematical form.[83]

[80] Kangas, Kangas, and Pykalainen, "Outranking Methods,"219.

[81] Kangas, Kangas, and Pykalainen, "Outranking Methods."

[82] Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 372.

[83] Yu-Hern Chang and Chung-Hsing Yeh, "Evaluating Airline Competitiveness Using Multi-Attribute Decision Making," *Omega the International Journal of Management Science* 29 (2001); 409, http://www.elsevier.com/locate/dsw (accessed January 4, 2008).

The assumption of the method is that each attribute has a monotonically increasing or decreasing utility which makes it easy to locate the positive and negative ideal solutions. The preference order of alternatives is found by comparing the Euclidean distances of alternatives to the ideal solutions (positive and negative). A decision matrix of *M* alternatives and *N* criteria is formulated firstly. Then the decision matrix is normalized and the weighted decision matrix is constructed. Next, the ideal and negative ideal solutions are found. The decision maker seeks to have maximum values for the benefit criteria and minimum values for the cost criteria among the alternatives. Then, separation measures are calculated, and finally relative closeness of each alternative to the ideal solution is determined. The best alternative (the alternative with the highest rank) is the one which has the shortest distance to the ideal solution and the longest distance to negative ideal solution.[84]

e. Compromise Programming (CP)

Compromise Programming (CP) is a multiple criteria decision making (MCDM) approach introduced by Yu and Zeleny in the 1970s. The main idea behind this approach is to determine a subset of efficient solutions (compromise set) that are nearest to an ideal and infeasible point (ideal point) in which all the criteria are optimized.[85] It defines the best solution as the one whose point is the least farthest from the ideal point in the set of efficient solutions. Finding a solution that is as close as possible to ideal is the aim of the approach. The distance measure used in CP is the family of L_p-metrics formulated below:[86]

$$L_p(a) = \sum_{j=1}^{j} w_j^p \left| f_j^* - f(a) \right| / \left| M_j - m_j \right|$$

where L_p *(a)* is the L_p metric of alternative a, *f (a)* is the value of alternative *a* for criterion *j*, M_j and m_j are the maximum (ideal) value and the minimum (anti ideal) value of

[84] Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 372.

[85] Francisco J. André and Carlos Romero, "On the Equivalence between Compromise Programming and the Use of Composite Compromise Metrics," (working paper, series: WP ECON 06.33, 2006), 2 http://ideas.repec.org/s/pab/wpaper.html (accessed December 25, 2007).

[86] Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 372.

criterion j in set A, f_j* is the ideal value of criterion j, w_j is the weight of the criterion j, and p is the parameter reflecting the attitude of the decision maker with respect to compensation between deviations. For $p = 1$, all deviations from f_j* are taken into account in direct proportion with their assigned weights.[87]

f. Multi-Attribute Utility Theory (MAUT)

Multi-attribute utility theory is another popular method for decision-making that is used to determine the best alternative among many and takes into consideration the decision maker's preferences in the form of the utility function which is defined over a set of attributes. In this method, all single attributes of an alternative (a product or a service) are evaluated to reach a final decision.[88]

It involves the following set of methods to make the best decision:

- "Define the alternatives and relevant attributes.
- Evaluate each alternative on each attribute. Remove dominated alternatives.
- Assign relative weights to the attributes.
- Combine the attribute weights and evaluations to yield an overall evaluation of each alternative.
- Perform sensitivity analysis and make a decision."[89]

The final value of an alternative is calculated by using the following formula:[90]

$$v(x) = \sum_{i=1}^{n} w_i v_i(x)$$

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87 Pohekar and Ramachandran, "Application of Multi-Criteria Decision Making," 372.

88 Bobbi Blaser Johnson, Eli Gratz, Kathy Longenecker Rust, and Roger Smith, "Multiattribute Utility Theory," (technical report, University of Wisconsin), http://www.r2d2.uwm.edu/atoms/archive/technicalreports/fieldscans/tr-mau.html#maut_at_outcomes (accessed December 11, 2007).

89 "Multi-Attribute Utility Theory," University of Illinois, http://pennmush.tinymush.org/~alansz/courses/mdm-block/maut.html (accessed December 11, 2007).

90 Ralph Schäfer, "Rules for Using Multi-Attribute Utility Theory for Estimating a User's Interests," Distributed System Institute, 3, http://www.kbs.uni-hannover.de/~henze/ABIS_Workshop2001/final/Schaefer_final.pdf (accessed December 16, 2007).

where $v_i(x)$ is the value (utility) function of an alternative against the i^{th} value dimension and w_i is the weight assigned to that value dimension. The sum of the all weights assigned to each value dimension equals to one and $v_i(x)$ is calculated by using relevant attributes of the value dimensions as[91]

$$v_i(x) = \sum_{a \in A_i} w_{ai} v_{ai}(l(a))$$

Here, A_i is the set of all attributes relevant for d_i, v_{ai} $(l(a))$ is the evaluation of the actual level $l(a)$ of attribute a on d_i, and w_{ai} is the weight that determines the impact of the evaluation of attribute a on value dimension d_i. The variable w_{ai} is also called the relative importance of attribute a for d_i. For all d_i $(i=1,...,n)$ holds $\sum_{a \in A_i} w_{ai} = 1$.

3. An Alternative Approach to Multi-Criteria Decision Making Techniques: Decision Support Systems (DSS) and Expert Systems

In some cases, decision makers do not have the adequate background knowledge to be able to understand and use the techniques which are briefly summarized above. Instead, these decision makers can use some software tools, which are built to use the techniques (one or some of them) with a user friendly interface, to get the support to make a decision. These support tools are decision support systems and expert systems.

"Decision Support Systems (DSS) are interactive information systems that rely on an integrated set of user-friendly decision support tools to produce and present information to support management in the decision making process."[92]

Most of the time, managers rely on their personal experience and the information that is available to help them in making decisions, but sometimes when encountering a real complex decision, their human abilities are not capable of evaluating for the best.[93]

91 Schäfer, "Rules for Using Multi-Attribute Utility Theory," 3.

92 Larry Long and Nancy Long, *Computers Information Technology in Perspective* (New Jersey: Pearson Education Inc. Press, 2005), 375.

93 Ibid.

When it is a complex decision, DSS helps decision makers to choose between alternatives and can even rank alternatives based on the user's preferences. Also, DSS can help managers to close the gap between the necessary information and available information.[94]

Decision support systems generally consist of a database, a knowledge base, a model base, and a user interface. The database provides the relevant historical data for the system to use in the model base. The knowledge base keeps the rules that are constraining the solution alternatives. The model base includes statistical, forecasting, simulation, and other math tools. The model base also provides users with appropriate tools without developing a model from the beginning. The user interface allows users to control the DSS easily and help them to decide which data and techniques to use in the analysis.[95]

The most important characteristics of DSS are helping decision makers, especially at tactical and strategic levels, in addressing semi-structured and unstructured problems, being interactive and user friendly, and being adaptable to meet the requirements of any decision.[96]

Data management, modeling, statistical analysis, planning, inquiry, representing information, and consolidation of similar information are the most important and common capabilities of DSS.[97]

Another type of information systems is Expert Systems (ES). "An Expert System is an interactive system that responds to questions, asks for clarification, makes recommendations, and generally helps the users in decision making process."[98] Expert systems are the simulation of the human thinking process, and it is like working with a

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[94] Long and Long, *Computers Information*, 375.

[95] Spainhower, "An Exploratory Study," 42.

[96] Long and Long, *Computers Information*, 375.

[97] Ibid., 376.

[98] Ibid., 379.

human expert to solve a problem. But, expert systems are better because they do not miss any important consideration or alternative. Expert systems are using if-then step-by-step rules to solve the problems.[99]

C. CONCLUSION

Multi-criteria decision analysis (MCDA) offers numerous methodologies and schools of thought for multi-criteria modeling and decision support, as the authors attempted to discuss the most popular ones in this chapter. The approaches vary from very simple ones to very complex optimization models.

The main aim of this study is to show the subjectivity involved in offeror (proposal) evaluation in the source selection part of government acquisitions. Therefore, the authors preferred to choose a technique that is simple to understand by anyone who does not have a multi-criteria decision making (MCDM) background. WSM is one of the very basic models/techniques used in situations where more than one criterion is involved and the relative importance of each criterion is different from each other. The model's biggest strength is its simplicity in application.

In the last thirty years, very different methods were developed in the area of MCDM. Most of the improvements are related with the setting of priorities (relative importance). Whenever the number of criteria increases and subcriteria exists, providing consistency of the relative importance becomes harder and harder. As stated before, this technique is one of the very basic methods; it is not providing a decision maker with a tool to determine the weights consistently. The decision maker has the responsibility to provide the consistency which is especially needed while assigning weights that is supposed to reflect their relative importance.

[99] Long and Long, *Computers Information*.

In this chapter, an overview on the available multi-criteria decision support tools and techniques was given. Among all these techniques, in this study one of the basic methods will be used to help the authors show the aim of their study. The next chapter will discuss the Air Force’s KC-X program in which the authors will use a simplified version of it in their study as a sample case.

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IV. USAF'S KC-X NEXT GENERATION TANKER PLANES PROGRAM

A. INTRODUCTION

In this part of the study, the authors will give some background information about the Air Force's KC-X program. The authors will use this program in their model to show the subjectivity involved in the source selection proposal evaluation part of Air Force's acquisitions. First, some introductory information about the program will be given, and then, the requirements will be explained in moderate detail. Next, background on how the competition began between two offerors will be discussed, and lastly, some specific information (to roughly compare the two alternatives) about each proposed aircraft will be presented.

The aim of the authors' project is to show the effects of the subjectivity involved in government procurement processes. Subjectivity involvement in the evaluation of the proposals in the source selection part of an acquisition is inevitable. However, subjectivity contrasts with fairness and best value. The authors try to show the effects of subjectivity involved in the process of selection by using a simplified and current real-life program.

The authors chose the USAF's KC-X program to study based upon their research. There are some specific reasons for the authors to choose that program. First of all, they wanted to show the effects of subjectivity, so they decided to choose an Air Force procurement program in which color ratings were used. This is because in the authors' perspective the Air Force's color rating is one of the most subjective techniques used in the government source selection.

The authors decided to study a program that was popular and current, as it was thought that they could have lots of different comments from a multitude of viewpoints. With a current program, they hoped to have more insight information, which was publicly available, about the program. Otherwise, most of the information about old programs is not accessible online because of confidentiality issues. Also, it was very clear that they would not be able to get any official information about an ongoing program but they thought that they could get enough data to do this study from the publicly available part of the data about the program. After all these considerations, they came up with the idea of doing their study on USAF's KC-X program.

After doing some research about the program, they realized that the two alternatives offered very different specifications and capabilities for the same program. This showed the authors the difference of the two offeror's point of view. The authors thought that this program might be a good sample for their study because of the potential effects of subjectivity.

Another factor that made the authors' choice even more interesting for the study is the high potential of the program to get protested. Experts of the defense industry were expecting a protest regardless of the winner. Since the proposed KC-X alternatives have very different strengths in terms of capabilities, results would not easily satisfy the offeror who lost the program award.

The acquisition of weapon systems has always been a crucial part of government acquisitions. They are crucial not only because of the dollar amount that goes along with these acquisitions, but also because the final product will be an important determinant factor in national security. Also, these programs take too much time and effort. Consequently, these projects may keep the U.S. as a super power and pioneer new technologies when they have successfully ended, but may keep the U.S. behind when they are not successful. There are other important factors that have impact on these processes like not having enough independent offerors and competition. Therefore, these projects are necessary but risky.

The Department of Defense (DOD) and the Air Force have become increasingly concerned about their aging aerial refueling aircraft because of the heavy pace of operations in support of the war on terrorism. The aerial refueling fleet was last reviewed by the Government Accountability Office (GAO) in 1996 and it was found that KC-135 aircraft were aging and becoming increasingly costly to maintain and operate.[100]

Currently, one of the biggest weapon systems projects is the U.S. Air Force's KC-X program. In January 2007, the solicitation for the KC-X project was advertised on the Federal Business Opportunities (FBO) website. The program has been planned for the production of 175 airplanes and 4 test platforms (i.e., a total of 179 airplanes). The cost objective for the first phase was approximately $40 billion. When the program was announced, the USAF declared their thoughts about renewing the Air Force's tanker fleet (America's current aerial tanker fleet is approximately 40-50 year old) project as their number one priority.[101]

The releases stated that "the Air Force also intends to take full advantage of the other capabilities inherent in the platform, and make it an integral part of the Defense Transportation System." Contending aircrafts were offering substantial improvements over the KC-135's extra capacity for cargo or people, in addition to their tanker roles.[102]

Lt. Gen. Donald Hoffman, the Assistant Secretary of the Air Force for Acquisition, announced the posting of the KC-X Aerial Refueling Aircraft RFP to the FBO website on January 30, 2007, signaling the official launch of the Air Force's number one priority acquisition program. The release noted that "The KC-X program is the first of three acquisition programs the Air Force will need to replace the entire fleet of aging KC-135 Stratotankers, which have been in service for more than 50 years". The RFP stipulated nine primary key performance parameters:[103]

1. Air refueling capability
2. Fuel offload and range at least as great as the KC-135

[100] U.S. General Accounting Office (GAO), *MILITARY AIRCRAFT: DOD Needs to Determine Its Aerial Refueling Aircraft Requirements*, GAO-04-349 Report June 2004, http://www.gao.gov/new.items/d04349.pdf (accessed March 11, 2008).

[101] August Cole, "Airbus to Raise Ante in Bid for Military-Tanker Deal", *Wall Street Journal*, January 14, 2008, 6, http://ebird.afis.mil/ebfiles/e20080114572969.html. (accessed January 21, 2008).

[102] "The USAF's KC-X Aerial Tanker RFP," http://www.defenseindustrydaily.com/the-usafs-kcx-aerial-tanker-rfp-03009/ (accessed February 1, 2008).

[103] "The USAF's KC-X Aerial Tanker RFP."

3. Compliant communication, navigation, surveillance/air traffic management (CNS/ATM) equipment
4. Airlift capability
5. Ability to take on fuel while airborne
6. Sufficient force protection measures
7. Ability to network into the information available in the battlespace
8. Survivability measures (defensive systems, Electro-Magnetic Pulse (EMP) hardening, chemical/biological protection, etc,)
9. Provisioning for a multi-point refueling system to support Navy and Allied aircraft

The USAF said that final RFP defined an integrated, capability-based, best-value approach, and included specific factors for assessing the capability contribution of each offeror, along with cost and assessments of past performance and proposal risk.

Also, it was announced by the Air Force that the department had gone through a careful review process for KC-X and had validated that the RFP had accurately reflected the requirements as laid out by the warfighter.

The Boeing 707-based KC-135 fleet ranges in age from 40 to 50 years old, raising the risk that fatigue or aging-related problems could ground them at some unanticipated time. Since aerial transport, fighter strike missions, bomber missions, and combat air patrols all depend on aerial refueling to some degree, a grounding of the KC-135 fleet could be catastrophic for America's military posture.[104]

The primary mission of the KC-X will be to provide aerial refueling to the United States military and coalition aircrafts in the war on terrorism and other missions. However, the Air Force also intends to take full advantage of the other capabilities inherent in the platform and make it an integral part of the Defense Transportation System. The RFP identified nine primary key performance parameters: addressing air refueling capabilities, including fuel, receiving fuel by aerial refueling from other

[104] "USAF KC-X: Will There Be a Competition?" http://www.defenseindustrydaily.com/usaf-kcx-will-there-be-a-competition-02994/ (accessed February 1, 2008).

platforms, and range at least equal to those of the existing KC-135. A new capability addressing joint operations will be the provisioning for a multi-point refueling system, to support Navy and allied aircraft.[105]

B. USAF'S REQUIREMENTS FOR KC-X

According to the Headquarters Air Mobility Command White Paper on KC-X, Joint Doctrine is the root of the requirement for a flexible Aerial Refueling Aircraft that can operate throughout a battlespace to deliver fuel and/or cargo and/or passengers. The Nation's new KC-X aircraft, which is required to be equipped with appropriate floors for carrying passengers and cargo, reasonably-sized doors to accommodate standard-sized pallets, and modest defensive systems which allow the aircraft access to an area of operations, will help US Combatant Commanders to success in their mission.[106]

Also, this document states that, US Joint Publications recognized the need for a refueling tanker to be able to manage different types of missions at the same time and have transferred these valuable lessons into current doctrine. For example, JP 3-17, one of the joint doctrines related with air mobility, states that all USAF tanker aircrafts are capable of performing an airlift role and are used to augment core airlift assets. Dual role concept demands an air refueling aircraft that can transport a combination of passengers and cargo while performing air refueling. The same concept states that in some circumstances, it may be more efficient employing an air refueling aircraft strictly in an airlift role. Air refueling units' deployment because of their organic capacity may be more effective to transport unit personnel and support equipment or passengers and cargo from other units.[107]

[105]"US Air Force's KC-X Aerial Tanker Replacement Program." http://www.defense-update.com/newscast/0107/news/300107_kcx.htm (accessed February 1, 2008).

[106] Headquarters Air Mobility Command White Paper, "KC-X: The Next Mobility Platform the Need for a Flexible Tanker." http://www-tc.pbs.org/newshour/bb/military/tanker_kc-x.pdf (accessed March 11, 2008).

[107] Headquarters Air Mobility Command White Paper, "KC-X: The Next Mobility Platform the Need for a Flexible Tanker."

The USAF announced its final solicitation (RFP) on January 30, 2007, and in its RFP, the USAF explained the requirements for the KC-X. Mission capability, proposal risk, past performance, cost/price, and the integrated fleet aerial refueling assessment (IFARA) will be the five main factors for the USAF's best value product evaluation for this program. The USAF explained this in their RFP numbered FA8625-07-R-6470 and dated January 30, 2007, as stated below,

> The Government will select the best overall offer, based upon an integrated assessment of Mission Capability, Proposal Risk, Past Performance, Cost/Price and the Integrated Fleet Aerial Refueling Assessment (IFARA). Contract(s) may be awarded to the offeror who is deemed responsible in accordance with the FAR, as supplemented, whose proposal conforms to the solicitation's requirements (to include all stated terms, conditions, representations, certifications, and all other information required by Section L of the solicitation) and is judged, based on the evaluation factors and subfactors, to represent the best value to the Government. The Government seeks to award to the offeror who gives Air Force the greatest confidence that it will best meet, or exceed, the requirements. This may result in an award to a higher rated, higher priced offeror, where the decision is consistent with the evaluation factors and the Source Selection Authority (SSA) reasonably determines that the technical superiority and/or overall business approach and/or superior past performance, and/or the IFARA of the higher priced offeror outweighs the cost difference. The SSA will base the source selection decision on an integrated assessment of proposals against all source selection criteria in the solicitation (described below). While the Government source selection evaluation team and the SSA will strive for maximum objectivity, the source selection process, by its nature, is subjective and, therefore, professional judgment is implicit throughout the entire process.[108]

The USAF will make the award to the best valued option. The evaluation will be made as explained in the RFP Section M. The main factors are given in the order of importance (mission capability, proposal risk, past performance, cost/price and IFARA) and for the USAF, the mission capability, proposal risk, and past performance evaluation factors are of equal importance and the cost/price and IFARA evaluation factors are also of equal importance. The first three evaluation factors are more important than the other two factors. The USAF explained this in their RFP as stated below,

[108] USAF's FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 1.

> Award will be made to the offeror submitting the most advantageous proposal to the Government based upon an integrated assessment of the evaluation factors and subfactors described below. The Mission Capability, Proposal Risk, and Past Performance evaluation factors are of equal importance and individually more important than either Cost/Price or IFARA evaluation factors individually. The IFARA is equal in importance to Cost/Price. Within the Mission Capability factor, the five (5) subfactors are listed in descending order of relative importance from 1 to 5. In accordance with FAR 15.304(e), the Mission Capability, Proposal Risk, Past Performance, and IFARA evaluation factors, when combined, are significantly more important than Cost/Price; however, Cost/Price will contribute substantially to the selection decision.[109]

Each of the five factors will be discussed separately to give more specific information about each of them and how they should be evaluated.

1. Factor 1: Mission Capability

The offeror's capability to satisfy the government's requirements will be assessed by the mission capability evaluation. This factor has 5 subfactors to evaluate. All mission capability subfactors will each receive one of the color ratings described in Air Force Federal Acquisition Regulation Supplement (AFFARS) in Mandatory Procedures part MP5315.3, paragraph 5.5.1 (blue-exceptional, green-acceptable, yellow-marginal, red-unacceptable). "Assessment will focus on the strengths and deficiencies of the offeror's proposal. The color rating represents how well the offeror's proposal meets the Mission Capability subfactor requirements." Mission Capability subfactor 5 will only receive 1 of the following 3 ratings: acceptable (green), marginal (yellow), or unacceptable (red)). There will not be any overall color rating, which is rolled up from subfactor ratings, for the mission capability factor.[110]

a. Subfactor 1: Key System Requirements

The first subfactor under mission capability is key system requirements. The offeror's understanding of the requirements (as defined in the system requirements

[109] USAF's FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 2.

[110] Ibid., 3.

document (SRD)) and how its ability to meet those requirements has substantiated will be evaluated under this subfactor. Only the logistics requirements as addressed in the Product Support section of subfactor 3 will not be evaluated herein subfactor 1.[111]

The government's evaluation of the offeror's approach to meet SRD requirements, according to the USAF's solicitation (RFP) document, numbered FA8625-07-R-6470, explained below.

Aerial refueling will include tanker aerial refueling, receiver aerial refueling, fuel offload versus radius range, drogue refueling systems (including simultaneous multipoint refueling), the operationally effective size of the boom envelope, the aerial refueling operator station and aircraft fuel efficiency. Airlift will include airlift efficiency, cargo, passengers, aero-medical evacuation, ground turn time, and cargo bay re-configuration. Operational Utility will include aircraft maneuverability, worldwide airspace operations, communication/information systems (including Net-Ready capability), treaty compliance support, formation flight, intercontinental range, 7,000 foot runway operations, bare base airfield operations, and growth provisions for upgrades. Survivability will include situational awareness, defensive systems against threats, chemical/biological capability, EMP protection, fuel tank fire/explosion protection, and night vision capability. Other system requirements will include all other SRD requirements that are not above (in Aerial Refueling, Airlift, Operational Utility and Survivability) or in Subfactor 3.[112]

b. Subfactor 2: System Integration and Software

The second subfactor under mission capability is system integration and software. This subfactor will evaluate the offeror's ability to implement disciplined and institutionalized systems engineering approach and the offeror's capability to manage and integrate the software elements to satisfy performance capability requirements in the KC-X's SRD. The USAF explained this in their RFP as stated below.[113]

[111] USAF's FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 3.

[112] Ibid., 6.

[113] Ibid.

> The Government will evaluate the proposal to determine the offeror's ability to implement a disciplined and institutionalized systems engineering approach necessary to successfully design, develop, integrate, validate and verify requirements, manufacture, and sustain the KC-X system as defined by the performance capability requirements set forth in the KC-X SRD. The software development capability (SDC) will be evaluated to determine the offeror's capability to manage and integrate the software elements required to satisfy the performance requirements.[114]

c. Subfactor 3: Product Support

Another subfactor under mission capability is product support. The offeror's proposed product support approach will be evaluated for an efficient, effective, and comprehensive support program for the service life of the KC-X fleet. The offeror's approach to achieve reliability, availability, maintainability, and supportability with an optimal logistics footprint will be evaluated by the government under this subfactor. Operational availability (Ao), reliability and maintainability (R&M), and mission capability (MC) rate will be the determination points of the government's evaluation.[115]

d. Subfactor 4: Program Management

The program management approach that the offeror will use for the KC-X program is also another important part of the mission capability factor. It is the fourth subfactor of mission capability. The government will evaluate the offeror's proposal to determine if the offeror is using a realistic and reasonable approach to effectively and efficiently implement and manage the KC-X program.[116]

The USAF explained how the realism and reasonableness determinations will be done in their RFP as stated below.

> **Realism** will be assessed to ensure the offeror's proposal reflects a clear understanding of program requirements, correlates to other program documentation, and is consistent with the approach described in the

[114] USAF's FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 5.

[115] Ibid., 6.

[116] Ibid., 7.

> technical volumes. **Reasonableness** will be assessed to ensure the proposed logic and methodology reflected in program documentation is acceptable and reflects an understanding of commonly accepted program management concepts and practices (emphasis added).[117]

e. Subfactor 5: Technology Maturity and Demonstration

The last of the subfactors of mission capability is technology maturity and demonstration, and this subfactor will evaluate the maturity of the critical technology elements (CTE) that are included in the offeror's proposed KC-X aircraft. These critical technology elements are described in the DoD Technology Readiness Assessment (TRA) Deskbook that can be accessed from the DoD's website. A CTE is an element that is new or novel or is being used in a new or novel way. It is critical if it is necessary to achieve the successful development of a system, its acquisition, or its operational utility. For example, a few of these can be mechanical components, processors, servers, electronics, and software (algorithm) interfaces. But, with the guidance provided by the DoD Technology Readiness Assessment (TRA) Deskbook, these elements are assessed for each program specifically.[118]

2. Factor 2: Proposal Risk

A proposal risk factor evaluation will be done at the mission capability subfactor level for only subfactors 1-4. The weaknesses associated with an offeror's proposed approach will be focused on while doing the proposal risk evaluation. This evaluation will try to determine the risks involved in program management objectives like cost, scheduling, and performance. An assessment of the potential for disruption of schedule, increased cost, degradation of performance, and the need for increased government oversight, as well as the likelihood of unsuccessful contract performance, will be the key points of this evaluation.[119]

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[117] USAF's FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 7.

[118] Ibid., 9.

[119] Ibid., 9.

The first four mission capability subfactors will receive one of the proposal risk ratings (high, moderate, low) described in AFFARS MP5315.3, paragraph 5.5.2. The risks related with the weaknesses or significant weaknesses of the offeror's proposed approach to each of the mission capability subfactors will be the focus of the evaluation. If any weakness is identified, then the evaluation will also focus on the offeror's proposed improvements and whether that approach is manageable or not.

3. Factor 3: Past Performance

The degree of confidence the government has in an offeror's ability to provide the product or service that meets warfighters' needs, including cost and schedule, is determined by the past performance evaluation factor and based on records of demonstrated performance.[120]

The Performance Confidence Assessment Group (PCAG) is the government evaluation team that will conduct an in-depth review and evaluation of all obtained performance data. The PCAG will work on both past and present performance data identified by offerors in their proposals and additional past and present performance data, if available from other sources. If necessary, the PCAG will also confirm the past and present performance data identified by offerors in their proposals. Additionally, the offeror's performance in managing and mitigating program risk will be assessed. After an evaluation of the offeror's recent past performance relevant to only mission capability subfactors 1-4 and cost/price, the government will assess an overall performance confidence. The overall past performance evaluation results will be the government's confidence in the offeror's ability to fulfill the solicitation requirements while meeting schedule, budget, and performance quality constraints.[121]

To also understand the government’s evaluation in a better way, some notions like performance confidence assessment, relevance, and offerors without a record of relevant

[120] USAF’s FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 9.

[121] USAF’s FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 10.

past performance and performance problems should be understood correctly. The AF explained these in their RFP as stated below,

> **Performance Confidence Assessment -** under the past performance factor, the performance confidence assessment represents the evaluation of an offeror's present and past work record in order to assess the government's confidence in the offeror's probability of successfully performing as proposed (emphasis added).[122]
>
> The performance confidence assessment will be assessed at the overall factor level after evaluating aspects of the offeror's recent past performance, focusing on performance that is relevant to the mission capability subfactors 1-4 only and cost or price…. Each offeror will receive one of the confidence ratings (high confidence, significant confidence, satisfactory confidence, unknown confidence, little confidence, or no confidence) as prescribed in AFFARS MP 5315.305 (August 10, 2005).[123]
>
> **Relevance -** the past performance evaluation is accomplished by reviewing aspects of an offeror's and major/critical subcontractor's relevant present and recent past performances (emphasis added).[124]
>
> Offerors without a record of relevant past performance or for whom information on past performance is not available will not be evaluated favorably or unfavorably based on past performance and, as a result, will receive an "**unknown confidence**" rating for the past performance factor (emphasis added).[125]
>
> Where relevant performance records indicate **performance problems**, the government will consider the number and severity of the problems as well as the appropriateness and effectiveness of any corrective actions taken (not just planned or promised). The government may review more recent contracts or performance evaluations to ensure corrective actions have been implemented and evaluate their effectiveness (emphasis added).[126]

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[122] USAF's FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 10.

[123] Ibid.

[124] Ibid.

[125] USAF's FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 11.

[126] Ibid.

4. Factor 4: Cost/Price

The cost/price evaluation will be done by using criteria to evaluate the current program costs, then the most probable life cycle cost (MPLCC) evaluation will be done, and finally proposals will be analyzed to determine whether or not they are unbalanced with respect to prices, quantity matrix factors, or separately priced line items.

Criteria, MPLCC and unbalanced pricing are the important points of the cost/price evaluation and the USAF explained these in their RFP as stated below.

- Criteria - the cost panel will evaluate the offeror's cost proposal against realism, reasonableness, and cost/price risk rating.[127]
- Most Probable Life Cycle Cost (MPLCC) is an independent government cost estimate, which is adjusted for technical, cost, and schedule risks, to include all contract, budgetary, and other government costs. Costs those are associated with all phases of the entire weapon system life cycle will be included. A work breakdown structured approach will be used to come up with an independent government cost estimate.[128]
- Unbalanced Pricing - proposals will be analyzed to determine whether or not they are unbalanced with respect to prices, quantity matrix factors, or separately priced line items. Unbalanced pricing exists whenever the total solicitation effort price is acceptable but, the price of one or more contract line items or a factor in the quantity matrices is significantly overstated or understated (can be demonstrated by the application of price analysis techniques in FAR 15.404-1 (b)).[129]

5. Factor 5: Integrated Fleet Aerial Refueling Assessment

The integrated fleet aerial refueling assessment (IFARA) factor evaluation will be done by using a scenario-based simulation program. An offeror’s KC-X fleet data from its proposal will be evaluated on a specific scenario by this simulation program to determine the number of KC-X to meet peak demand for mission accomplishment. The same scenario will evaluate the number of KC-135R needed to accomplish the mission instead of KC-X. For comparison, the number of KC-135R needed for the mission will be

[127]USAF’s FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 12.

[128] Ibid., 13.

[129] USAF’s FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 14.

divided by the number of KC-X needed. This ratio will be called the fleet effectiveness value and will show the effectiveness of KC-X instead of KC-135R. A fleet effectiveness value of 1.0 will be assessed as equal in effectiveness to the KC-135R, so a fleet effectiveness value greater than 1.0 will be assessed as more effective than the KC-135R and more advantageous to the government. The USAF explained the IFARA factor in their RFP as stated below,

> The Government will use modeling and simulation to provide an integrated assessment of the utility and flexibility for a fleet of the offeror's proposed KC-X by evaluating the number of aircraft required to fulfill the peak demand of the aerial refueling elements evaluated in the 2005 Mobility Capability Study (MCS). In the context of this evaluation scenario, the Government will determine the proposed KC-X's fleet effectiveness in relation to a KC-135R fleet.[130]
>
> The Government will conduct the analysis using offeror-provided data in the evaluation scenario by primarily using the Combined Mating and Ranging Planning System (CMARPS) modeling and simulation tool. The results of the CMARPS evaluation will provide the Government with the quantity (based on the offeror-proposed KC-X aircraft) required to meet the mission requirements of the evaluation scenario. The same scenario will be run on CMARPS using a KC-135R fleet to provide a baseline quantity for comparison. The required number of KC-135R aircraft generated by the model will be divided by the number of proposed KC-X aircraft required to meet the same scenario. This ratio is the "fleet effectiveness value" for the proposed KC-X aircraft.[131]
>
> The Government will report the "fleet effectiveness value" as determined by the evaluation as a standalone "value" to the SSA, along with any major insights and observations gleaned from the evaluation. This value will be determined by Government analysis taking into account the offeror's input data and considering any analysis performed by the offeror of the same evaluation scenario.[132]

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[130] USAF’s FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 14.

[131] USAF’s FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 15.

[132] Ibid.

C. BOEING AND NORTHROP GRUMMAN-EADS TEAM COMPETED FOR KC-X PROGRAM

Shortly after the AF released its RFP, Boeing and Northrop Grumman-European Aeronautic Defense and Space Company (EADS) announced that they would bid on the program, and the two teams began competing for this contract award. On one side was the Boeing team with KC-767 Advanced (767-200 derivative) and on the other was the Northrop Grumman-EADS's team with KC-30B (Airbus A330-200/200F derivative). Approximately a year after solicitation, final proposals were submitted on January 3, 2008.[133]

Both teams waited hopefully for the results which were publicly announced on February 29, 2008. The Northrop Grumman-EADS (Airbus) team was announced as the winner of this program and it was a surprise for lots of people who were expecting Boeing to win (Airbus is an aircraft manufacturing subsidiary of EADS).

The announcement, available on DOD's website about the USAF's aerial tanker program award, stated the contract award as follows;

> Northrop Grumman Corp., of Los Angeles, Calif., is being awarded a cost plus incentive/award fee, fixed price incentive, firm fixed price contract for the newly-named KC-45. This contract is awarded after full and open bidding, and provides for the system design and development of four test aircraft for $1.5B. This contract also includes five production options targeted for 64 aircraft at $10.6B. At this time no funds have been obligated. Contracting activity is the Aeronautical Systems Center, Wright-Patterson Air Force Base, Ohio (contract number FA8625-08-C-6451).[134]

On March 7, 2008, Air Force and Boeing officials came together for a formal debriefing. After a thorough analysis of data presented at this debriefing on the decision, Boeing concluded that the Air Force's efforts to run a fair, open, and transparent competition failed due to irregularities that placed Boeing at a competitive disadvantage

[133] "The USAF's KC-X Aerial Tanker RFP."

[134] U.S. Department of Defense, "Contract Announcement webpage," http://www.defenselink.mil/contracts/contract.aspx?contractid=3719 (accessed March 1, 2008).

throughout this competition. Boeing claimed that because of these irregularities they were penalized for offering a commercial-derivative airplane with lower costs and risks and greater protection for troops.[135]

On March 11, 2008, Boeing filed a formal protest to the Government Accountability Office (GAO) claiming that there were irregularities with the process of the competition and the evaluation of the competitors' bids and cited these irregularities, which are not fully available to the public, in their formal protest. The protest was not a surprise for defense industry experts because of the huge difference between the offered products of the two competing offerors for the same requirements. Thus, experts were expecting a protest from the losing party (either Boeing or NG-Airbus). In the protest, Boeing's main point was the size of NG-Airbus's KC-X since the AF formerly announced this program as a replacement program for the KC-135 and also announced that there would be another program to replace KC-10s (KC-10 is an aircraft that is almost two times larger than the KC-135). The NG-Airbus team proposed an aircraft that was even bigger than the KC-10 for the KC-135 replacement program, so Boeing has asked the agency to review the USAF's decision to award a contract to the Northrop Grumman and EADS team to replace aerial refueling tankers.[136]

Boeing's Vice President and Tanker Program Manager, Mark McGraw, said that their analysis of the data presented by the Air Force showed that the competition was seriously flawed and resulted in the selection of the wrong airplane for the warfighters. He also talked about their concerns about the USAF's evaluation and expressed that they were exercising their protesting process. The GAO will review the decision to ensure that the process was fair and the results were the best choice for the U.S. warfighters and taxpayers.[137]

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[135] Boeing, "Boeing Protests U.S. Air Force Tanker Contract Award," http://www.boeing.com/news/releases/2008/q1/080311b_nr.html (accessed March 12, 2008).

[136] Boeing, "Boeing Protests U.S. Air Force Tanker Contract Award."

[137] Ibid.

D. INFORMATION ABOUT KC-X ALTERNATIVES

The aim of this project is to show the effects of subjectivity involved in the source selection phase of acquisition because of the techniques used in proposal evaluations. The authors try to show the effects of subjectivity by using the KC-X program, but they do not try to make the proposal evaluation for the KC-X program. Even if they wanted to do the evaluation for proposals, they would need lots of experts and much time like the Air Force did. Since the authors want to work on realistic data, they use the data about the program that was publicly available. The authors expect to have more realistic results this way. All the information the authors used were from offerors' websites for this specific program and the product cards of the proposed aircrafts. Also, they have another source of information, which is the publicly available part of Boeing's protest file. The authors work on the KC-X program with this publicly available information.

Since the entire program's goal is to replace the aging KC-135s with their new alternative, all mission capability requirements include the KC-135 as the base point. Therefore, the authors provide some very basic capabilities of the KC-135 in this study, which will be very helpful for one to understand the USAF's comparisons as well as the capabilities of the new alternatives in a better way.

While the KC-135s can carry up to 6 standard 463L cargo pallets, 53 people, or about 18 medical litters, according to the KC-30 team's (Northrop Grumman-EADS) official brochure, their A330-200/200F derivative can carry up to 32 standard 463L cargo pallets, up to 226 passengers, or 120 medical litters, or some combination of the above, in addition to its full fuel load. Team Boeing's KC-767 Advanced can carry up to 19 standard 463L cargo pallets, up to 190 passengers, or 54 medical litters, or some combination of the above, in addition to its full fuel load.

The exact amount of fuel that the US KC-767 Advanced can carry is not public. The base figure of around 200,000 pounds is similar to the existing KC-135, but the additional body tank option is a wild card. The KC-767's advanced refueling boom has a 900 gallon/minute capacity and been tested successfully in live air-to-air refuelings. While the KC-30 can carry over 250,000 pounds of capacity, it also carries more fuel than the 767, which is a particular advantage in the Pacific sector with its wide over-water expanses. On the other hand, its advanced 1,200 gallon/minute ARBS refueling boom has yet to actually transfer fuel to another aircraft in the air. Figure 3 illustrates the size comparison of the KC-30, KC-767AT and KC-135.

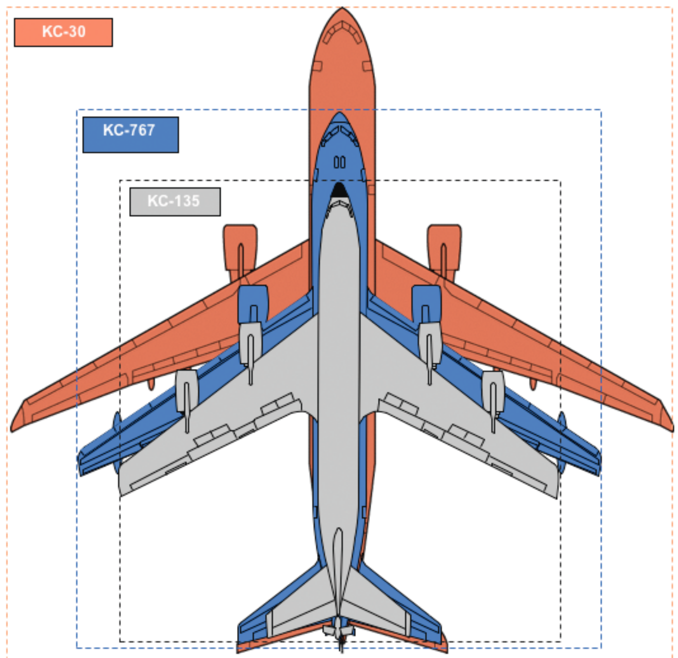

Figure 3. Size Comparison of the KC-30, KC-767AT and KC-135 (Source: Boeing's KC-767's product card).

The KC-30 is approximately two times larger than the KC-135 and also approximately one and a half times larger than the 767, which requires a slightly longer runway and costs more to operate on a per-plane basis. Team KC-30 stresses costs and efficiency on a per-mission basis, and if larger tanker aircraft with more fuel and cargo space mean fewer sorties required, the figures may look more equal once the mission the tankers are supporting is complete.[138]

As their relative capacities demonstrate, the KC-767 is a smaller aircraft than the KC-30. One positive consequence is that it can take off from slightly shorter runways. The USAF requires the ability to take off from an 8,000 foot runway, but would prefer 7,000 feet as this makes more runways available. Boeing also claims the KC-767 as being

[138] "The USAF's KC-X Aerial Tanker RFP."

22 to 24 percent cheaper to operate and maintain on a per-plane basis than the KC-30, and its base aircraft is cheaper to buy on the civilian market.[139]

Figure 4 below is the evaluation summary table taken from Boeing's protest file (the publicly available part of the protest file). These are the evaluation summary results that Boeing claims that the AF came up with at the end of its evaluations on proposals.[140]

Evaluation Summary of Factors

Factors	Boeing		NG	
Mission Capability/Proposal Risk				
Key System Requirements	B	L	B	L
System Integration & Software	G	M	G	M
Product Support	B	L	B	L
Program Management	G	L	G	L
Technology Maturity & Demonstration	G	NA	G	NA
Performance Confidence	Satisfactory		Satisfactory	
Cost/Price				
Reasonableness	Yes		Yes	
Realistic	Yes		Yes	
Balanced Offer	Yes		Yes	
MPLCC (TY$)	$108,044M		$108,010M	
Cost Risk Rating (SDD – P&D)	Moderate – Low		Low – Low	
IFARA	1.79		1.90	

Figure 4. Evaluation Summary Table taken from Boeing's Protest File.

This figure was removed from Boeing's publicly available protest file after the USAF and NG separately made objections against it because it included proprietary information.

However, the authors will use these evaluation results from the evaluation summary table presented above. In this study, the aim is to show the subjectivity involved in source selection, especially in the color rating method; therefore, the evaluation result in this study will not be an alternative evaluation for the KC-X program.

139 "The USAF's KC-X Aerial Tanker RFP."

140 Boeing, Boeing's Protest File (publicly available part), http://www.boeing.com/ids/globaltanker/pdf/executive_summary.pdf (accessed March 18, 2008).

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V. MODEL CONSTRUCTION

A. INTRODUCTION

In this study, two models that have been built via the use of Microsoft Excel are presented in two versions to show different characteristics of two types of methods that can be used in the source selection phase in government acquisitions. These methods are the color rating method, which is the current method used by the Air Force, and the quantitative weighted sum method. In the study, the authors have added a numerical structure to the color rating method to be able to perform their analysis. Since it is not possible to compare numerical and adjective information and make an analysis, the authors have converted the color/adjectival ratings into numerical points using a way that will be thoroughly explained in this chapter.

The models have been established using some data from the Air Force's current KC-X Tanker Replacement Program and proposals of its two offerors, Boeing and Northrop/Airbus.

In version one of the authors' models, they used exact color and adjectival ratings given in the KC-X solicitation and determined the ranges that are used to assign numerical points to factors and subfactors centered on a basic logic. On the other hand, in the second version, the authors eliminated some color and adjectival ratings and changed the structures of the ranges to be able to respond to some complicated needs. The details about both versions will be provided in the authors' model building explanations.

B. MODEL BUILDING OF VERSION ONE

In model building for version one, the authors will use a model for color rating evaluations and will use another model for weighted sum method evaluations. The idea behind these models is to show the difference between two techniques for the same purpose and also to show how the result will be affected. The steps that compose the version one models with detailed explanations will start with the color rating model and after finishing it completely, the weighted sum method model will be explained.

1. The Model Using the Color Rating Method

The model building for the color rating method will consist of the following eight steps:

1. Determining factors and subfactors
2. Determining relative importance of factors and subfactors
3. Evaluating the proposed systems and giving ratings to factors and subfactors
4. Assigning weights to factors and subfactors based on their relative importance
5. Determining the ranges of ratings and the ranges' midpoints
6. Assigning the related values for those ratings
7. Calculating weighted ratings and final ratings
8. Comparing both offeror's final ratings and deciding on the winner

a. Determine Factors and Subfactors

Factors and subfactors are the discriminators against which each offeror's proposal is evaluated. Factors without any subfactors as well as factors with several subfactors are possible in big government acquisitions. In the KC-X program, the factors and subfactors were presented in the solicitation as follows:

- Factor 1: Mission Capability
  - Subfactor 1: Key System Requirements (KSR)
  - Subfactor 2: System Integration and Software (SIS)
  - Subfactor 3: Product Support (PS)
  - Subfactor 4: Program Management (PM)
  - Subfactor 5: Technology Maturity and Demonstration (TMD)
- Factor 2: Proposal Risk
- Factor 3: Past Performance

- Factor 4: Cost/Price
- Factor 5: Integrated Fleet Aerial Refueling Assessment (IFARA)

In the proposal risk assessment, the offerors are evaluated at the mission capability subfactor level using the first four subfactors, which are key system requirements, system integration and software, product support, and program management. Therefore, these four factors are considered as subfactors in the proposal risk assessment in the authors' models.

Furthermore, a cost/price risk evaluation as well as life cycle cost is included in the cost/price factor assessment. Hence, there are two subfactors, life cycle cost and cost risk, under this factor.

In the integrated fleet aerial refueling assessment, the "fleet effectiveness value", which is the standalone value that will be reported to the Source Selection Authority (SSA) according to the solicitation, will be the only consideration point on this factor.

After these explanations the final form for the factors and subfactors will be as follows:

- Factor 1: Mission Capability
  - Subfactor 1: Key System Requirements (KSR)
  - Subfactor 2: System Integration and Software (SIS)
  - Subfactor 3: Product Support (PS)
  - Subfactor 4: Program Management (PM)
  - Subfactor 5: Technology Maturity and Demonstration (TMD)
- Factor 2: Proposal Risk
  - Subfactor 1: Key System Requirements (KSR)
  - Subfactor 2: System Integration and Software (SIS)
  - Subfactor 3: Product Support (PS)
  - Subfactor 4: Program Management (PM)
- Factor 3: Past Performance

- Factor 4: Cost/Price
    - Subfactor 1: Life Cycle Cost
    - Subfactor 2: Cost Risk
- Factor 5: Integrated Fleet Aerial Refueling Assessment (IFARA)

b. Determine Relative Importance of Factors and Subfactors

In the KC-X solicitation, the relative importance of factors and subfactors is given using narrative explanations and terms like “significant”, “more important,” “equal,” or “less important”. As an important point, in the color rating method, a mathematical differential between factors and subfactors using terms like “twice as important as” is not assigned.[141]

The relative importance of factors and subfactors is provided in the KC-X solicitation as follows:

> The Mission Capability, Proposal Risk, and Past Performance evaluation factors are of equal importance and individually more important than either Cost/Price or IFARA evaluation factors individually. The IFARA is equal in importance to Cost/Price. Within the Mission Capability factor, the five (5) subfactors are listed in descending order of relative importance from 1 to 5. In accordance with FAR 15.304(e), the Mission Capability, Proposal Risk, Past Performance, and IFARA evaluation factors, when combined, are significantly more important than Cost/Price; however, Cost/Price will contribute substantially to the selection decision.[142]

As stated above, mission capability, proposal risk, and past performance, and on the other side cost/price and IFARA, are equally important, whereas the first three factors are individually more significant than either cost/price or IFARA. Also, the order of relative importance for the mission capability subfactors is as follows:

1. Key System Requirements (KSR)
2. System Integration and Software (SIS)
3. Product Support (PS)

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[141] Slate, “Best Value Source Selection,” 52.

[142] USAF’s FA8625-07-R-6470 numbered Solicitation (RFP) Document, Section M, 2.

4. Program Management (PM)
5. Technology Maturity and Demonstration (TMD)

On the other hand, under the cost/price factor, it has been assumed that life cycle cost is more important than the cost risk assessment when its real importance as stated in the solicitation is considered.

c. *Evaluate the Proposed Systems and Assign Ratings to Factors and Subfactors*

In this phase of the authors' model building, they have mainly used the data they gathered from different sources, i.e., bidders' web sites. In this way, the authors' goal is to maintain realism throughout their models. Color and adjectival ratings are assigned to factors and subfactors for each offeror based on the merits of their proposals.

At this point, it should be stated that the Source Selection Authority (SSA) is supposed to make its decision based on these color and adjectival ratings after this step. However, because it is so complicated to make a decision based on these ratings and consistency is so important while evaluating both offerors, the SSA should use a type of numerical method. Based on this logic, the authors have built the rest of their color rating model using some numerical ways.

d. *Assign Weights to Factors and Subfactors Based on Their Relative Importance*

In the authors' models, they have arbitrarily assigned some specific weights to factors and subfactors to be able to reflect their real importance levels as given in the RFP. Without finding an appropriate way to reflect these importance levels, it is impossible to be consistent while evaluating both offerors, and assigning numerical weights is the most easy and non-complex way to accomplish this goal. As an example, because mission capability is more important than cost/price according to the solicitation, mission capability should get a higher weight than cost/price.

On the other hand, at each level of factors and subfactors, the sum of weights should be equal to 100 to maintain consistency. Figure 5 depicts the weights the authors assigned.

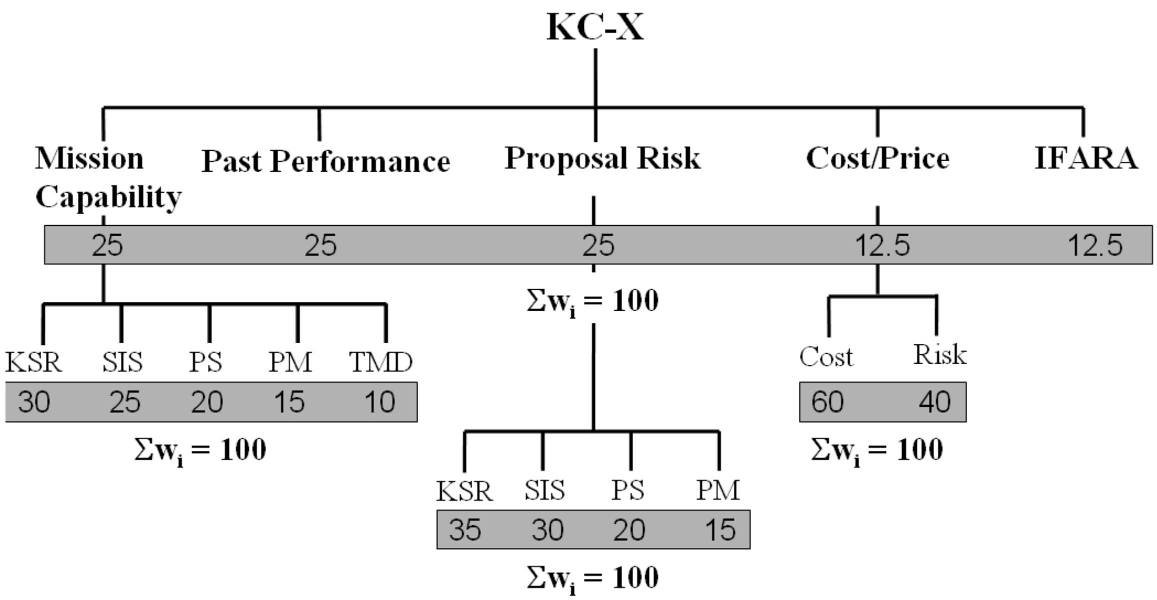

Figure 5. The Weights of the Factors and the Subfactors.

e. Determine the Ranges of Ratings and the Ranges' Midpoints

In order to combine weights and ratings at the last phase of the evaluation and reach an overall rating, each color rating and adjectival rating should get a numerical value. Therefore, in the authors' model building, they have initially established some numerical ranges that represent each color and adjectival rating and are set between numbers 0 and 100.

It was stated before that any factor or subfactor except life cycle cost and IFARA, which get numerical values, can get any color or adjectival rating based on the value an offeror proposes. In order to show which points between 0 and 100 represent which color or adjectival rating, a number of ranges should be determined based on the number of color or adjectival ratings possible for a factor or a subfactor.

In this part of the authors' study, the ranges for each color or adjectival rating are set as equal. For example, when there are four color ratings, each color rating will have a range of 25 points on a 100-point scale. Choosing unequal ranges is investigated in an upcoming section.

Additionally, the authors have to assign only one numerical rating to each color or adjectival rating and that numerical point should be a number among the numbers in the range that rating is associated with. In this study, the authors have assigned the midpoints of the ranges to the color and adjectival ratings because a midpoint is the most appropriate value that can represent the color or adjectival rating in a range.

The following diagrams in Figure 6 show the ranges and the midpoints for the subfactors.

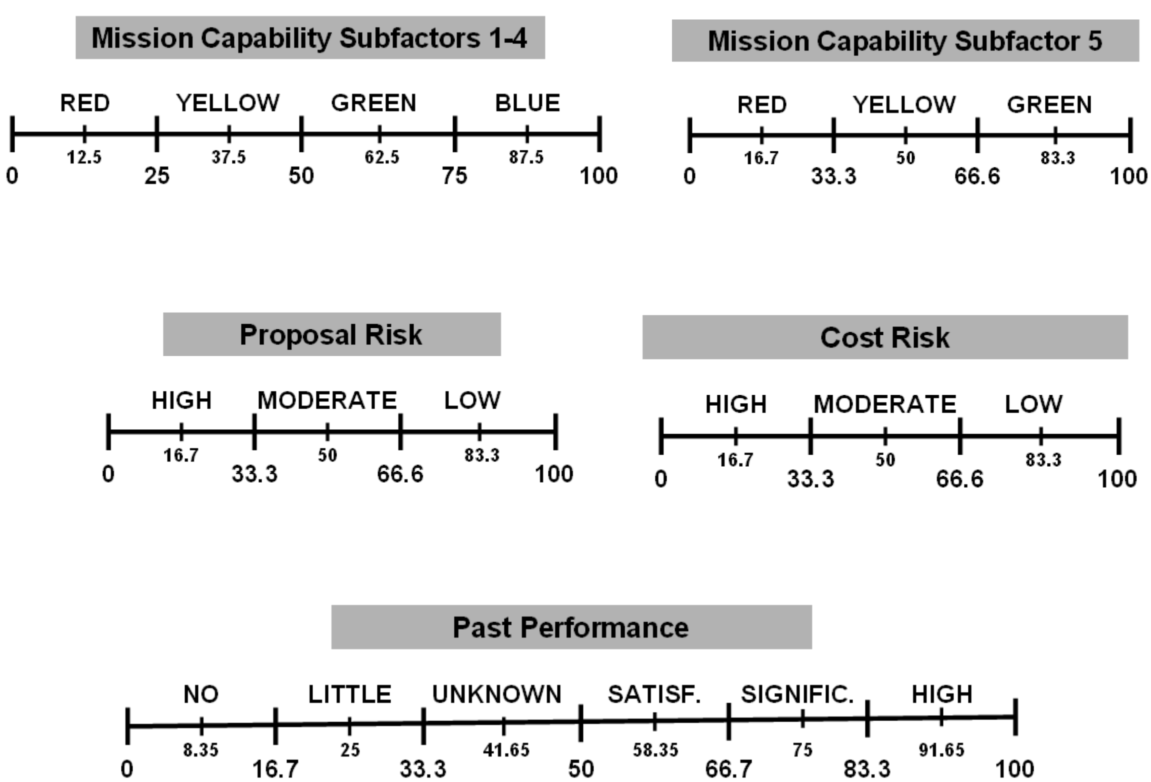

Figure 6. The Ranges and the Midpoints of the Factors and the Subfactors for Version One.

As a last point, it has been assumed that the cost range is between 105 and 110 billion dollars because the estimated life cycle cost is about 108 billion dollars. Additionally, the IFARA range is between 0.75 and 2.00 because the real IFARA values of the offerors are 1.79 and 1.90 and the authors wanted to take into account the values below 1 in this version.

f. Assign the Related Values to the Ratings

The midpoints determined before for each numerical range were assigned to the color and adjectival ratings. In this way, a combination of these points and numerical weights will be possible to reach an overall rating for an offeror.

g. Calculate Weighted Ratings and Final Ratings

In this phase, weighted ratings are calculated by the multiplication of weights and assigned midpoints. For past performance and IFARA, the factors that do not have any subfactors, only one calculation is enough to reach the overall factor rating. However, for other factors that have subfactors, one more calculation is needed to reach the overall factor rating. After having all factor ratings, an overall offeror rating is obtained by using the same calculation.

The basic calculation used in this step is shown below;

Factor or Subfactor Rating = (Factor or Subfactor Weight) * (Assigned Midpoint)

Throughout the authors' study, they have taken advantage of the software program Microsoft Excel that can make these kinds of calculations fast and let users easily change inputs to see instantaneous changes on outputs. The authors are going to explain how they have used Excel during this phase of their study on two examples.

Before any action, the appearance of the spreadsheet for the mission capability subfactors is shown in Figure 7.

	A	B	C	D	E	F	G	H
1								
2		MISSION CAPABILITY			WEIGHTS	RATING	WEIGHTED	
3		SUBFACTORS					RATING	
4		KSR			0.30	0	0	
5		SIS			0.25	0	0	
6		PS			0.20	0	0	
7		PM			0.15	0	0	
8		TMD			0.10	0	0	
9							0	
10								

Figure 7. The Appearance of the Color Rating Method Spreadsheet for the Mission Capability Subfactor before Any Action in Version One.

For the mission capability subfactor key system requirements, after evaluation of the proposed system the user enters an assessed color rating into cell C4. As soon as the user enters the rating into cell C4, Excel assigns the associated midpoint into cell F4 (refer to Figure 8).

	A	B	C	D	E	F	G	H
1								
2		MISSION CAPABILITY			WEIGHTS	RATING	WEIGHTED	
3		SUBFACTORS					RATING	
4		KSR	GREEN		0.30	62.5	18.75	
5		SIS			0.25	0	0	
6		PS			0.20	0	0	
7		PM			0.15	0	0	
8		TMD			0.10	0	0	
9							18.75	
10								

Figure 8. The Appearance of the Color Rating Method Spreadsheet for the Mission Capability Subfactor after Entering the First Color Rating in Version One.

To be able to assign the true midpoint associated with any color rating, the F4 cell as seen in Figure 8 has the following formula:

=IF(C4="BLUE",87.5,IF(C4="GREEN",62.5,IF(C4="YELLOW",37.5,IF(C4="RED", 12.5,0))))

This formula tells Excel to assign 87.5 if the color rating is blue, 62.5 if the color rating is green, 37.5 if the color rating is yellow, 12.5 if the color rating is red, or 0 for other entries. Since green has been entered into cell C4, Excel assigned 62.5 into cell F4. Also, the multiplication of weight (E4) and numerical rating (F4) gives the weighted rating.

After entering all assessed color ratings into cells C4-C8, Excel assigns related midpoints into cells F4-F8, which have the same formula above (except F8 because Technology Maturity and Demonstration (TMD) subfactor does not get a blue rating and has different midpoints) with true cell names, and all weighted ratings are calculated via the scheme stated above. As a final step, Excel instantaneously adds all weighted ratings and the overall numerical rating for the mission capability factor, which is 52.08 in this example, is reached (refer to Figure 9).

	A	B	C	D	E	F	G	H
1								
2		MISSION CAPABILITY			WEIGHTS	RATING	WEIGHTED	
3		SUBFACTORS					RATING	
4		KSR	GREEN		0.30	62.5	18.75	
5		SIS	YELLOW		0.25	37.5	9.375	
6		PS	RED		0.20	12.5	2.5	
7		PM	BLUE		0.15	87.5	13.125	
8		TMD	GREEN		0.10	83.3	8.33	
9							52.08	
10								

Figure 9. The Appearance of the Color Rating Method Spreadsheet for the Mission Capability Subfactor after Entering All Color Ratings in Version One.

As a second example, the appearance of the spreadsheet for the cost/price factor before any entry is given below in Figure 10.

	A	B	C	D	E	F	G	H
1								
2		COST/PRICE SUBFACTORS			WEIGHTS	RATING	WEIGHTED RATING	
3								
4		COST			0.60	0	0	
5		RISK			0.40	0	0	
6							0	
7								

Figure 10. The Appearance of the Color Rating Method Spreadsheet for the Cost/Price Subfactors before Any Action in Version One.

For the cost/price subfactor cost, the user enters the life cycle cost the offeror proposes into cell C4. As soon as the user enters the cost data into cell C4, Excel assigns the associated numerical rating into cell F4 (refer to Figure 11).

Due to the fact that the life cycle cost range is between 105 and 110 billion dollars, F4 cell has the following formula:

=IF (C4==0, 0, 2200-(20*C4))

This formula tells Excel to assign 0 points into cell F4 whenever there is no value assigned and whenever a value is assigned, the formula will use the equation to calculate the rating. For instance, if the proposed cost is 110 billion dollars, Excel will assign 0 points into cell F4 and 100 points if the proposed cost is 105 billion dollars.

	A	B	C	D	E	F	G	H
1								
2		COST/PRICE SUBFACTORS			WEIGHTS	RATING	WEIGHTED RATING	
3								
4		COST	107		0.60	60	36	
5		RISK			0.40	0	0	
6							36	
7								

Figure 11. The Appearance of the Color Rating Method Spreadsheet for the Cost/Price Subfactors after Entering the LCC in Version One.

For the cost/price subfactor risk, after evaluation of the proposed system, the user enters the assessed adjectival rating into cell C5. As soon as the user enters the rating into cell C5, Excel assigns the associated midpoint into cell F5 (refer to Figure 12 below).

	A	B	C	D	E	F	G	H
1								
2		COST/PRICE SUBFACTORS			WEIGHTS	RATING	WEIGHTED RATING	
3								
4		COST	107		0.60	60	36	
5		RISK	LOW		0.40	83.3	33.32	
6							69.32	
7								

Figure 12. The Appearance of the Color Rating Method Spreadsheet for the Cost/Price Subfactors after Entering All Ratings in Version One.

To be able to assign the true midpoint associated with any adjectival rating, the F5 cell has the following formula:

=IF (C5="HIGH",16.7,IF(C5="MODERATE",50,IF(C5="LOW",83.3,0)))

This formula tells Excel to assign the value of 16.7 if the adjectival rating is high, 50 if the rating is moderate, 83.3 if the rating is low, or 0 for all other entries. Since low has been entered into cell C5, Excel has assigned 83.3 to cell F5. Also, the multiplication of weight (E5) and numerical rating (F5) gives the weighted rating. As a final step, Excel instantaneously adds all weighted ratings, and the overall numerical rating for cost/price factor, which is 69.32 in this example, is obtained.

Finally, after all factor ratings are obtained and weighted factor ratings are computed using factor weights assigned in step (d), an overall offeror rating is reached by adding all weighted factor ratings. The final appearance of an example spreadsheet in which the overall offeror rating is 58.2025 is given below in Figure 13.

	A	B	C	D	E	F	G
1							
2		FACTORS		WEIGHTS	RATING	WEIGHTED RATING	
3							
4		Mission Capability		0.250	52.08	13.02	
5		Proposal Risk		0.250	63.32	15.83	
6		Past Performance		0.250	58.35	14.5875	
7		Cost/Price		0.125	69.32	8.665	
8		IFARA		0.125	48.80	6.1	
9			OVERALL OFFEROR RATING:			58.2025	
10							

Figure 13. Overall Offeror Ratings for Version One.

h. Compare Both Offeror's Final Ratings and Decide the Winner

As the last phase, the two offerors are compared using their overall numerical ratings and the offeror that has higher point wins the competition. Thus, the contract is awarded to that offeror.

An example snapshot of the version one color rating spreadsheet as a whole is presented in the Appendix part of the study.

2. The Model Using the Quantitative Weighted Sum Method

This method consists of the same steps like the color rating method except steps (e) and (f), because numerical ratings instead of color or adjectival ratings are used in the quantitative weighted sum method and thus there is no need to determine any range and the associated midpoint. In this method the proposed systems of the offerors are given numerical ratings, not color or adjectival ratings, between 0 and 100 for each factor and subfactor, and after calculating the weighted ratings using assigned weights, the sum of the weighted numerical ratings provides the overall rating for each offeror.

Hence, the steps that compose the quantitative weighted sum method are as follows:

1. Determine factors and subfactors
2. Determine relative importance of factors and subfactors
3. Evaluate the proposed systems and give numerical ratings to factors and subfactors
4. Assign weights to factors and subfactors based on their relative importance
5. Calculate weighted ratings
6. Compare both offeror's final ratings and decide the winner

The important point to emphasize about this model is the fact that any number between 0 and 100 can be assigned to any factor or subfactor. Therefore, when it is considered that in the color rating method, only a few numerical values can be assigned to each factor or subfactor, the quantitative weighted sum method is more sensitive to small differences between offerors. For instance, although two offerors that propose products with little differences and one of which is better than the other get most likely the same color ratings, when the quantitative weighted sum method is used, the difference between offerors will be noticeable because of dissimilar assigned numerical ratings.

In this model building phase, the authors have once again taken advantage of Microsoft Excel and its user friendly spreadsheets. One example is going to be used to explain how Excel was used in this phase of the authors' study.

For the proposal risk factor, the appearance of the spreadsheet before any action is shown in Figure 14.

	A	B	C	D	E	F
1						
2		PROPOSAL RISK		WEIGHTS	WEIGHTED RATING	
3						
4		KSR		0.35	0	
5		SIS		0.30	0	
6		PS		0.20	0	
7		PM		0.15	0	
8					0	
9						

Figure 14. The Appearance of the Weighted Sum Method Spreadsheet for the Proposal Risk Factor before Any Action in Version One.

For the proposal risk subfactor key system requirements, after evaluation of the proposed system, the user enters an assessed numerical rating into cell C4. As soon as the user enters the rating into cell C4, Excel computes the weighted rating by multiplying that rating with the related weight and assigns that weighted rating into cell E4 (refer to Figure 15 below).

PROPOSAL RISK		WEIGHTS	WEIGHTED RATING
KSR	71	0.35	24.85
SIS		0.30	0
PS		0.20	0
PM		0.15	0
			24.85

Figure 15. The Appearance of the Weighted Sum Method Spreadsheet for the Proposal Risk Factor after Entering the First Rating in Version One.

After entering all the assessed numerical ratings into cells C4-C7, Excel calculates all weighted ratings and assigns them into cells E4-E7. As a final step, Excel instantaneously adds all weighted ratings and the overall numerical rating for the proposal risk factor, which is 58.95 in this example, is determined (see Figure 16).

PROPOSAL RISK		WEIGHTS	WEIGHTED RATING
KSR	71	0.35	24.85
SIS	42	0.30	12.6
PS	88	0.20	17.6
PM	26	0.15	3.9
			58.95

Figure 16. The Appearance of the Weighted Sum Method Spreadsheet for the Proposal Risk Factor after Entering All Ratings in Version One.

An example snapshot of the version one weighted sum method spreadsheet as a whole is presented in the Appendix part of the study.

C. MODEL BUILDING OF VERSION TWO

In this version of the authors' model, the authors have made some changes on the color and adjectival ratings as well as the ranges that are used to determine the numerical midpoints for the ratings.

First of all, the authors have eliminated some color or adjectival ratings that reflect the lowest values for factors or subfactors. For instance, the red color rating for the mission capability subfactors has been discarded because the authors thought it is reasonable to assume that an offeror who gets a red for any mission capability subfactor, which is one of the most critical requirement of a program, does not deserve to compete any more for the contract because of its unacceptable offer. As another example, a high adjectival rating for the proposal risk factor and cost risk subfactor has also been eliminated to disqualify any offeror who puts high risk on the program's goals.

In addition to eliminating some ratings, the authors have extended or narrowed the numerical ranges to which color and adjectival ratings are related. The logic behind this is actually the desire to value an offeror who proposes to provide more valuable product to the government. For instance, narrowing the numerical range of blue, which is the highest color rating for the mission capability subfactors, increases the likelihood an offeror who really deserves and gets that rating will win the contract. On the other hand, extending the numerical range of green through high points makes it difficult to get a blue rating.

The following diagrams depicted in Figure 17 show the new ranges and the midpoints for the factors and subfactors.

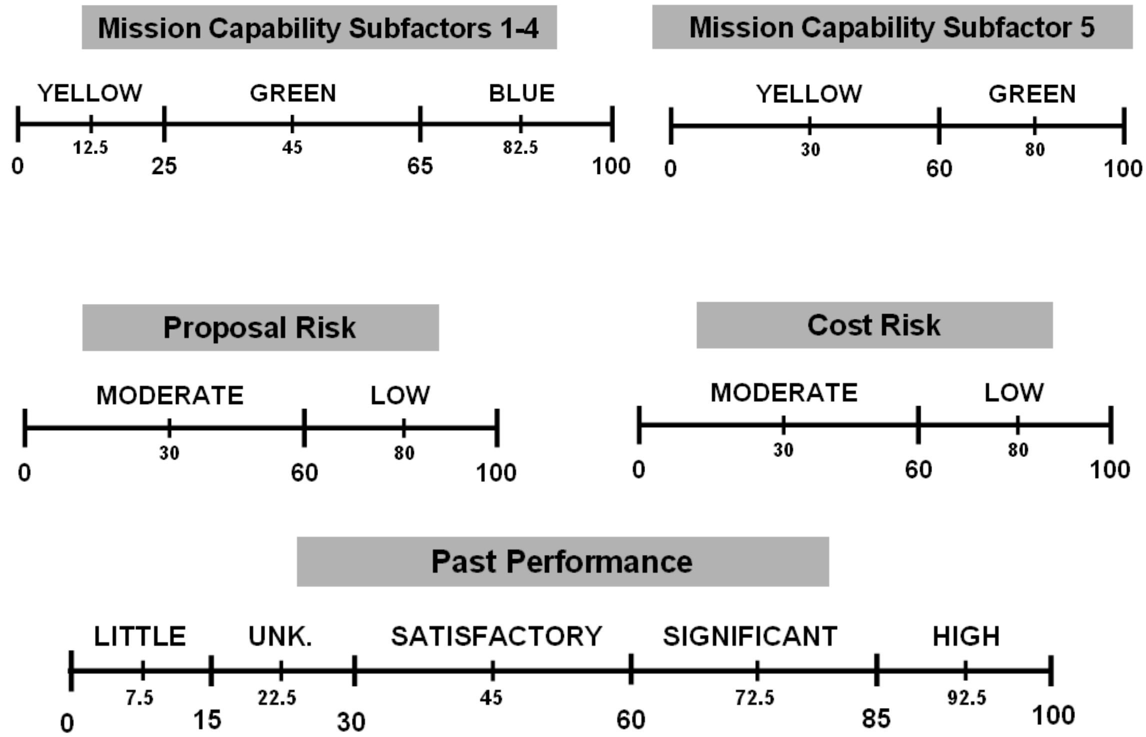

Figure 17. The Ranges and the Midpoints of the Factors and the Subfactors for Version Two.

As a last point, in this version of the authors' study, the IFARA range is considered between 1.00 and 2.00 to disqualify any offeror whose proposed system gives a fleet effectiveness value of less than one because it has been assumed that a tanker aircraft which is not even as effective as the KC-135 can not meet government best value requirements. The remainder of each model is completely as same as the initial ones.

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VI. ANALYSIS AND RESULTS

A. INTRODUCTION

In the KC-X Tanker Replacement Program, which is the most significant procurement program in the Air Force recently, the Air Force has used its current source selection method, color rating, and the Airbus/Northrop Grumman team won the contract. After debriefings presented to both offerors, the fact has emerged that the ratings of both offerors are almost same and they are very similar where they are not exactly the same. Consequently, long debates have begun between Boeing and the Air Force and Boeing has filed a protest with the Government Accountability Office (GAO) asking the agency to review the award decision.

What if the Air Force had used a numerical method to determine the winner, not the color rating method? Could Boeing have won the contract and be the USAF's choice to build the nation's next generation tanker plane?

This is the question that the authors are going to answer in this chapter based on the models explained previously. In this chapter, two versions of the authors' models will be presented and it will be demonstrated on two versions that if the Air Force had used the weighted sum method to determine the winner, Boeing might have won the contract. This result is based on hypothetical data that would have resulted in the actual color/adjectival ratings given in Figure 4. This result will prove that Air Force's source selection process using the color rating method has some subjectivity and using a numerical method might give completely different results, thus leading another offeror to end up as the winner.

One important point to state is that while assigning numerical points to each evaluation subfactor in the quantitative weighted sum method, the authors have assigned values among the numbers falling in the range of the associated color or adjectival rating to demonstrate that Boeing could have had the better offer. For instance, in version one, the mission capability assessment for Boeing when using the quantitative weighted sum method; the authors have assigned 93 (which is a pretty high rating) to the key system requirements subfactor. They did so because they had to select a number that would be able to represent the blue rating and, therefore, a number between 75 and 100, which is the numerical range for the blue color rating in version one.

B. THE ANALYSIS OF VERSION ONE

Version one of the authors' model has been built based on a basic logic in which the ranges of color and adjectival ratings are evenly distributed and all color/adjectival ratings are taken into account during the evaluations. Version two, which will be analyzed later in the chapter, excludes some of the color/adjectival ratings.

In this part, first of all, each evaluation factor will be analyzed separately for both offerors using both methods and overall factor ratings will be obtained. After that, overall offeror ratings will be calculated and the differences between those overall ratings will be examined.

There are four tables in each factor assessment part below. The first tables demonstrate Boeing's color ratings assigned to each subfactor under each factor for the color rating method, and the second tables show its numerical ratings assigned to the same subfactors for the quantitative weighted sum method with consideration given to the numerical ranges of the color ratings assigned in the color rating method.

On the other hand, the third tables demonstrate Airbus's color ratings assigned to each subfactor under each factor for the color rating method, and the fourth ones show its numerical ratings assigned to the same subfactors for the quantitative weighted sum method considering the numerical ranges of the color ratings assigned in the color rating method. Besides, overall factor ratings for each offeror calculated using both methods are shown below in tables.

As explained before in Chapter V, in models using the color rating method the authors have converted the color ratings into numerical ratings using range midpoints in order to be able to determine an overall score to compare the color rating method and the weighted sum method. In the models using the weighted sum method, the numerical values for each factor and subfactor were selected by the authors, because true values were not available, to demonstrate how other values within the same color ranges could yield different overall results. Also, all weights used to show importance levels of factors and subfactors were selected by the authors with consideration given to the importance level requirements in the RFP.

1. Mission Capability Factor Assessment

The tables demonstrating both offerors' ratings obtained by using both methods for the mission capability factor are provided below in Tables 7 and 8.

Using Color Rating (Table-1)

MISSION CAPABILITY SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
KSR	BLUE	0.30	87.5	26.250
SIS	GREEN	0.25	62.5	15.625
PS	BLUE	0.20	87.5	17.500
PM	GREEN	0.15	62.5	9.375
TMD	GREEN	0.10	83.3	8.330
				77.080

Using WSM Rating (Table-2)

MISSION CAPABILITY SUBFACTORS		WGHT	WEIGHTD RATINGS
KSR	93	0.30	27.90
SIS	64	0.25	16.00
PS	92	0.20	18.40
PM	63	0.15	9.45
TMD	94	0.10	9.40
			81.15

Table 7. Mission Capability Factor Assessment for Boeing.

Using Color Rating (Table-3)

MISSION CAPABILITY SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
KSR	BLUE	0.30	87.5	26.250
SIS	GREEN	0.25	62.5	15.625
PS	BLUE	0.20	87.5	17.500
PM	GREEN	0.15	62.5	9.375
TMD	GREEN	0.10	83.3	8.330
				77.080

Using WSM Rating (Table-4)

MISSION CAPABILITY SUBFACTORS		WGHT	WEIGHTD RATINGS
KSR	81	0.30	24.30
SIS	60	0.25	15.00
PS	90	0.20	18.00
PM	58	0.15	8.70
TMD	85	0.10	8.50
			74.50

Table 8. Mission Capability Factor Assessment for Airbus.

As seen on the tables above, while Boeing and Airbus both get 77.08 as their overall mission capability factor rating when the color rating method is used because they have the same color ratings for these subfactors, Boeing gets 81.15 and Airbus gets 74.50

when the numerical method is used. This result demonstrates that although both offerors received the same color ratings, Boeing could possibly have proposed a technically better product to the government.

2. Proposal Risk Factor Assessment

Tables 9 and 10 show proposal risk assessment results of both offerors obtained via both methods.

Using Color Rating (Table-1)

PROPOSAL RISK SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
KSR	LOW	0.35	83.3	29.155
SIS	MODERATE	0.30	50.0	15.000
PS	LOW	0.20	83.3	16.660
PM	LOW	0.15	83.3	12.495
				73.310

Using WSM Rating (Table-2)

PROPOSAL RISK SUBFACTORS		WGHT	WEIGHTD RATINGS
KSR	94	0.35	32.90
SIS	57	0.30	17.10
PS	97	0.20	19.40
PM	94	0.15	14.10
			83.50

Table 9. Proposal Risk Factor Assessment for Boeing.

Using Color Rating (Table-3)

PROPOSAL RISK SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
KSR	LOW	0.35	83.3	29.155
SIS	MODERATE	0.30	50.0	15.000
PS	LOW	0.20	83.3	16.660
PM	LOW	0.15	83.3	12.495
				73.310

Using WSM Rating (Table-4)

PROPOSAL RISK SUBFACTORS		WGHT	WEIGHTD RATINGS
KSR	85	0.35	29.75
SIS	57	0.30	17.10
PS	91	0.20	18.20
PM	87	0.15	13.05
			78.10

Table 10. Proposal Risk Factor Assessment for Airbus.

For the proposal risk factor, because both offerors have received the same adjectival ratings, they get 73.31 as their overall proposal risk factor rating. However, when the quantitative weighted sum method is used, while Airbus gets 78.10, Boeing gets a higher score of 83.50. This result demonstrates that although both offerors received the same color ratings, Boeing could have proposed a product to the government which is less risky for the program’s objectives.

3. Past Performance Assessment

Both offerors' ratings obtained by using both methods for the past performance factor are provided below in Tables 11 and 12.

Using Color Rating (Table-1)

PAST PERFORMANCE	RATING
SATISFACTORY	58.35
	58.35

Using WSM Rating (Table-2)

PAST PERFORMANCE	RATING
59	59

Table 11. Past Performance Assessment for Boeing.

Using Color Rating (Table-3)

PAST PERFORMANCE	RATING
SATISFACTORY	58.35
	58.35

Using WSM Rating (Table-4)

PAST PERFORMANCE	RATING
56	56

Table 12. Past Performance Assessment for Airbus.

For the past performance factor, both offerors have received the rating of 'satisfactory' which results in the same score for both offerors when the color rating method is used. However, Boeing gets a higher point value when the numerical method is used because of the assumption that its past performance is better than Airbus's.

4. Cost/Price Factor Assessment

Below are the tables showing the cost/price factor assessment results obtained using both methods of both offerors (Tables 13 and 14).

Using Color Rating (Table-1)

COST/PRICE SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
COST	108.044	0.60	39.12	23.472
RISK	MODERATE	0.40	50.00	20.000
				43.472

Using WSM Rating (Table-2)

COST/PRICE SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
COST	108.044	0.60	39.12	23.472
RISK	58	0.40	58.00	23.200
				46.672

Table 13. Cost/Price Factor Assessment for Boeing

Using Color Rating (Table-3)

COST/PRICE SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
COST	108.01	0.60	39.8	23.88
RISK	LOW	0.40	83.3	33.32
				57.20

Using WSM Rating (Table-4)

COST/PRICE SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
COST	108.01	0.60	39.80	23.88
RISK	70	0.40	70.00	28.00
				51.88

Table 14. Cost/Price Factor Assessment for Airbus.

The tables above show that when the color rating method is used, Airbus gets a considerably higher score than Boeing in regards to the cost/price factor. However, when the quantitative weighted sum method is used, the difference between each offeror's cost/price factor ratings substantially shrinks because of selecting a high point (58.00) among points falling in the 'moderate' risk rating numerical range (i.e., 33-66) and assigning it as the Boeing's numerical rating for the cost risk subfactor. The assumption for assigning a high point value representing the 'moderate' risk rating to Boeing is that it might have proposed a life cycle cost that put some risk on the program's goals and that risk was slightly more than what is allowed in order to get a 'low' risk rating.

5. Integrated Fleet Aerial Refueling Assessment (IFARA)

Below in Tables 15 and 16 are the evaluations of the IFARA factor for both offerors using both methods. Since there is not any subfactor under the IFARA factor and no color or adjectival ratings have been used in this factor evaluation, no difference can be observed between each offeror's ratings. Airbus gets a higher point value than Boeing because of its higher fleet effectiveness value using both methods.

Using Color Rating

IFARA	RATING
1.79	83.2
	83.2

Using Numerical Rating

IFARA	RATING
1.79	83.2
	83.2

Table 15. Integrated Fleet Aerial Refueling Assessment (IFARA) for Boeing.

Using Color Rating

IFARA	RATING
1.9	92
	92

Using Numerical Rating

IFARA	RATING
1.9	92
	92

Table 16. Integrated Fleet Aerial Refueling Assessment (IFARA) for Airbus.

6. Conclusion

The tables presenting all weighted subfactor ratings and calculated overall offeror ratings for both methods and offerors are provided below in Tables 17 and 18.

Using Color Rating

FACTORS	WGHT	RATNG	WEIGHTD RATING
Mission Capability	0.250	77.08	19.270
Proposal Risk	0.250	73.31	18.328
Past Performance	0.250	58.35	14.588
Cost/Price	0.125	43.47	5.434
IFARA	0.125	83.20	10.400
OVERALL OFFEROR RATING:			68.019

Using WSM Rating

FACTORS	WGHT	RATNG	WEIGHTD RATING
Mission Capability	0.250	81.15	20.288
Proposal Risk	0.250	83.50	20.875
Past Performance	0.250	59.00	14.750
Cost/Price	0.125	46.67	5.834
IFARA	0.125	83.20	10.400
OVERALL OFFEROR RATING:			72.147

Table 17. Overall Scores for Boeing.

Using Color Rating

FACTORS	WGHT	RATNG	WEIGHTD RATING
Mission Capability	0.250	77.08	19.270
Proposal Risk	0.250	73.31	18.328
Past Performance	0.250	58.35	14.588
Cost/Price	0.125	57.20	7.150
IFARA	0.125	92.00	11.500
OVERALL OFFEROR RATING:			70.835

Using WSM Rating

FACTORS	WGHT	RATNG	WEIGHTD RATING
Mission Capability	0.250	74.50	18.625
Proposal Risk	0.250	78.10	19.525
Past Performance	0.250	56.00	14.000
Cost/Price	0.125	51.88	6.485
IFARA	0.125	92.00	11.500
OVERALL OFFEROR RATING:			70.135

Table 18. Overall Scores for Airbus.

The results are really noteworthy considering the importance of the KC-X Tanker Replacement Program. As easily seen above, there are two different winners to whom the contract should be awarded when using two kinds of methods. When using the color rating method, Airbus gets a score of 70.835 and Boeing gets a score of 68.019, which means Airbus deserves to get the contract. On the other hand, when the quantitative weighted sum method is used, Airbus gets an overall score of 70.135 and Boeing gets 72.147, so the winner should be Boeing.

The implication under these results is that when there are little but important differences between offerors, the color rating method is potentially incompetent in reflecting those differences. However, the quantitative weighted sum method is capable of handling those little details and providing more accurate results.

The snapshots of all the models and a comparison chart for version one can be found in the Appendix part of the study.

C. THE ANALYSIS OF VERSION TWO

As explained in the previous chapter, version two differs from version one based on some changes of the color/adjectival ratings and the ratings' numerical ranges. Initially, the color/adjectival ratings that reflect the lowest values for factors/subfactors are eliminated and, then, the numerical ranges to which the color and adjectival ratings are related to are extended or narrowed. For instance, the high adjectival rating for the proposal risk factor and cost risk subfactor has been eliminated to disqualify any offeror who puts high risk on the program's goals, and the range of the low risk rating has been narrowed to value the offeror who proposes a less risky product to the government. More detailed explanations about the logic behind these changes were provided in the previous chapter.

In this part, first of all, each evaluation factor will be analyzed separately for both offerors using both methods. After overall factor ratings are obtained, overall offeror ratings will be calculated and the differences between those overall ratings will be discussed.

There are four tables in each factor assessment part below. The first tables demonstrate Boeing's color ratings assigned to each subfactor under each factor for the color rating method, and the second tables show its numerical ratings assigned to the same subfactors for the quantitative weighted sum method with consideration given to the numerical ranges of the color ratings assigned in the color rating method.

On the other hand, the third tables demonstrate Airbus's color ratings assigned to each subfactor under each factor for the color rating method, and the fourth ones show its numerical ratings assigned to the same subfactors for the quantitative weighted sum method considering the numerical ranges of the color ratings assigned in the color rating method. Besides, overall factor ratings for each offeror calculated using both methods are shown below the tables.

At this point, the authors want to remind the reader that the difference between the analysis tables for versions one and two is that in version two the color rating method rating values reflect new midpoints for the color ratings.

1. Mission Capability Factor Assessment

The tables showing the mission capability factor assessment results of both offerors that were obtained using both methods are provided below in Tables 19 and 20.

Using Color Rating (Table-1)

MISSION CAPABILITY SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
KSR	BLUE	0.30	82.50	24.75
SIS	GREEN	0.25	45.00	11.25
PS	BLUE	0.20	82.50	16.50
PM	GREEN	0.15	45.00	6.75
TMD	GREEN	0.10	80.00	8.00
				67.25

Using WSM Rating (Table-2)

MISSION CAPABILITY SUBFACTORS		WGHT	WEIGHTD RATINGS
KSR	93	0.30	27.90
SIS	64	0.25	16.00
PS	92	0.20	18.40
PM	63	0.15	9.45
TMD	94	0.10	9.40
			81.15

Table 19. Mission Capability Factor Assessment for Boeing.

Using Color Rating (Table-3)

MISSION CAPABILITY SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
KSR	BLUE	0.30	82.50	24.75
SIS	GREEN	0.25	45.00	11.25
PS	BLUE	0.20	82.50	16.50
PM	GREEN	0.15	45.00	6.75
TMD	GREEN	0.10	80.00	8.00
				67.25

Using WSM Rating (Table-4)

MISSION CAPABILITY SUBFACTORS		WGHT	WEIGHTD RATINGS
KSR	81	0.30	24.30
SIS	60	0.25	15.00
PS	90	0.20	18.00
PM	58	0.15	8.70
TMD	85	0.10	8.50
			74.50

Table 20. Mission Capability Factor Assessment for Airbus.

Since Boeing and Airbus have the same color ratings for the mission capability subfactors, they both get 67.25 as their overall factor rating when the color rating method is used. However, when the quantitative weighted sum method is used, Boeing gets a score of 81.15 and Airbus gets 74.50. The answer to how Boeing may get a higher score when the numerical method is used is hidden behind the features of the quantitative weighted sum method. Due to the fact that it is more capable of showing little differences between offerors, the final scores may be very different although they may be exactly the same when the color rating method is used. In this particular case, Boeing might have proposed a more technically capable product to the government.

2. Proposal Risk Factor Assessment

The proposal risk factor assessment tables that demonstrate all scores for both offerors and methods are shown below in Tables 21 and 22.

Using Color Rating (Table-1)

PROPOSAL RISK SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
KSR	LOW	0.35	80.00	28.00
SIS	MODERATE	0.30	30.00	9.00
PS	LOW	0.20	80.00	16.00
PM	LOW	0.15	80.00	12.00
				65.00

Using WSM Rating (Table-2)

PROPOSAL RISK SUBFACTORS		WGHT	WEIGHTD RATINGS
KSR	94	0.35	32.90
SIS	57	0.30	17.10
PS	97	0.20	19.40
PM	94	0.15	14.10
			83.50

Table 21. Proposal Risk Factor Assessment for Boeing.

Using Color Rating (Table-3)

PROPOSAL RISK SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
KSR	LOW	0.35	80.00	28.00
SIS	MODERATE	0.30	30.00	9.00
PS	LOW	0.20	80.00	16.00
PM	LOW	0.15	80.00	12.00
				65.00

Using WSM Rating (Table-4)

PROPOSAL RISK SUBFACTORS		WGHT	WEIGHTD RATINGS
KSR	85	0.35	29.75
SIS	57	0.30	17.10
PS	91	0.20	18.20
PM	87	0.15	13.05
			78.10

Table 22. Proposal Risk Factor Assessment for Airbus.

These results are very similar to the previous ones. Although both offerors get the very same score, which is 65, for the proposal risk factor when the color rating method is used, Boeing's score is higher than the Airbus score when the quantitative weighted sum method is used. The possible reason for this is that Boeing proposed a product that puts lower risk on the schedule, cost and performance goals even though they received the same adjectival ratings.

3. Past Performance Assessment

The tables of the past performance assessment for both offerors using both methods are given below in Tables 23 and 24.

Using Color Rating (Table-1)

PAST PERFORMANCE	RATING
SATISFACTORY	45
	45

Using WSM Rating (Table-2)

PAST PERFORMANCE	RATING
59	59

Table 23. Past Performance Assessment for Boeing.

Using Color Rating (Table-3)

PAST PERFORMANCE	RATING
SATISFACTORY	45
	45

Using WSM Rating (Table-4)

PAST PERFORMANCE	RATING
56	56

Table 24. Past Performance Assessment for Airbus.

For the past performance factor, both offerors have received the rating of 'satisfactory' that causes the same score for both offerors when the color rating method is used. However, Boeing gets a higher point value when the numerical method is used because of the assumption that its past performance is better than Airbus and almost high enough to get a 'significant' past performance rating.

4. Cost/Price Factor Assessment

Tables 25 and 26 show the cost/price factor assessment results of both offerors that were obtained using both methods.

Using Color Rating (Table-1)

COST/PRICE SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
COST	108.044	0.60	39.12	23.472
RISK	MODERATE	0.40	30.00	12.000
				35.472

Using WSM Rating (Table-2)

COST/PRICE SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
COST	108.044	0.60	39.12	23.472
RISK	58	0.40	58.00	23.200
				46.672

Table 25. Cost/Price Factor Assessment for Boeing.

Using Color Rating (Table-3)

COST/PRICE SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
COST	108.01	0.60	39.80	23.88
RISK	LOW	0.40	80.00	32.00
				55.88

Using WSM Rating (Table-4)

COST/PRICE SUBFACTORS		WGHT	RATNG	WEIGHTD RATINGS
COST	108.01	0.60	39.80	23.88
RISK	70	0.40	70.00	28.00
				51.88

Table 26. Cost/Price Factor Assessment for Airbus.

For the cost/price factor, Airbus always gets a relatively higher score than Boeing when either method is used because of its 'low' cost risk rating. However, as easily seen on the tables above, the difference between the overall factor ratings of the offerors diminish when the quantitative weighted sum method is used. The assumption that leads the authors to reach this result is that while Boeing might have proposed a life cycle cost that is not realistic enough to get a 'low' risk rating but very close to it, Airbus might have proposed a cost that is slightly more realistic than Boeing and is able get a 'low' risk rating.

5. Integrated Fleet Aerial Refueling Assessment (IFARA)

The evaluations of the IFARA factor for both offerors obtained using both methods are given below in Tables 27 and 28.

Using Color Rating (Table-1)

IFARA	RATING
1.79	79
	79

Using WSM Rating (Table-2)

IFARA	RATING
1.79	79
	79

Table 27. Integrated Fleet Aerial Refueling Assessment (IFARA) for Boeing.

Using Color Rating (Table-3)

IFARA	RATING
1.9	90
	90

Using WSM Rating (Table-4)

IFARA	RATING
1.9	90
	90

Table 28. Integrated Fleet Aerial Refueling Assessment (IFARA) for Airbus.

Since the IFARA assessment does not include any color/adjectival rating, there is no difference between each offeror's ratings. Airbus gets a higher point score than Boeing because of its higher fleet effectiveness value using both methods.

6. Conclusion

The tables presenting all weighted subfactor ratings and calculated overall offeror ratings for both methods and offerors are provided below in Tables 29 and 30.

Using Color Rating

FACTORS	WGHT	RATNG	WEIGHTD RATING
Mission Capability	0.250	67.250	16.813
Proposal Risk	0.250	65.000	16.250
Past Performance	0.250	45.000	11.250
Cost/Price	0.125	35.472	4.434
IFARA	0.125	79.000	9.875
OVERALL OFFEROR RATING:			58.622

Using WSM Rating

FACTORS	WGHT	RATNG	WEIGHTD RATING
Mission Capability	0.250	81.150	20.288
Proposal Risk	0.250	83.500	20.875
Past Performance	0.250	59.000	14.750
Cost/Price	0.125	46.672	5.834
IFARA	0.125	79.000	9.875
OVERALL OFFEROR RATING:			71.622

Table 29. Overall Scores for Boeing.

Using Color Rating

FACTORS	WGHT	RATNG	WEIGHTD RATING
Mission Capability	0.25	67.25	16.813
Proposal Risk	0.25	65.00	16.250
Past Performance	0.25	45.00	11.250
Cost/Price	0.125	55.88	6.985
IFARA	0.125	90.00	11.250
			62.548

Using WSM Rating

FACTORS	WGHT	RATNG	WEIGHTD RATING
Mission Capability	0.250	74.50	18.625
Proposal Risk	0.250	78.10	19.525
Past Performance	0.250	56.00	14.000
Cost/Price	0.125	51.88	6.485
IFARA	0.125	90.00	11.250
			69.885

Table 30. Overall Scores for Airbus.

Version two of the authors' model, which suggests a different way to evaluate both offerors, results in the same significant result as was obtained in the first version. In this version, although Airbus gets the higher overall score, which is 62.548, when the color rating method is used, it gets a lower overall score, which is 69.885, when the quantitative weighted sum method is used. Therefore, there is a change in the winner and Boeing gets the contract when the numerical method is used.

This part of the authors' study supports their argument that the quantitative weighted sum method is more competent than the color rating method in reflecting the little but important differences between offerors.

The snapshots of all the models and a comparison chart for version two can be found in the Appendix part of the study.

In the following chapter, three different factors will be evaluated to understand their effects on the results via sensitivity analysis. Sensitivity analysis will be performed to demonstrate how these results are impacted by changing the choice of weights. In addition, how susceptible these results are to the selection of the rating values with the color ranges will be explored.

VII. SENSITIVITY ANALYSIS

A. INTRODUCTION

In this chapter, the authors will investigate how modeling choices might affect the results that were presented in the previous chapter. In the previous chapter, the authors' study results support their argument that the quantitative weighted sum method is more competent than the color rating method in reflecting the little but important differences between offerors. The color rating method is potentially incompetent in reflecting those differences.

In this part of the study, sensitivity analysis will be done to understand the effects and limits of ratings (within color ranges) and weights in the models. Three different forms of sensitivity analysis will be done. In the first one, numerical ratings for the color and adjectival ratings will be changed within their ranges to see the best/worst possible overall scores for each alternative in version one of the authors' model. In the second one, the same analysis that will be done in the first sensitivity analysis will be applied to the authors' version two model (with a diminished number of color and adjectival ratings). In the third final one, the weights will be changed. While keeping original model ratings as constant, the authors will analyze the effects of weights on results. The last analysis will be done for each alternative and for the color and weighted sum method (WSM) rating techniques.

B. FIRST SENSITIVITY ANALYSIS

In the previous chapter, the results show that while Airbus wins the contract with the color rating method evaluations, in the WSM evaluation Airbus loses it with numerical scores that are in the same color ranges (numerical equivalents of color ratings). Based on these results, the authors decided to perform a sensitivity analysis to understand the effects of the color rating ranges on the results. The authors will keep the color rating ranges as constant and will change the numerical ratings that are equivalent to those color ratings in the possible rating ranges. The research question is "How sensitive is the overall WSM score to different numerical ratings within each color range?” This will give the authors the best and the worst overall score that each company could get using the numerical model of their study (while keeping numerical ratings within color ranges for assigned colors).

The authors used the formula on the following page to do the first part of their sensitivity analysis. To calculate the best overall score, the authors needed a maximization model for the objective function, and to calculate the worst overall score, they needed a minimization model for the objective function. Each (max and min) model was implemented twice - one for Boeing and one for Airbus.

The formulation on the next page is for Boeing in version one of the authors’ model. With some little changes, this formula adapted to Airbus so that the same analysis could be performed. The following model will be solved once for maximization and the results will give the best possible score for Boeing with the assigned color and adjectival rating ranges in the first version of the authors’ model. Next, it will be solved for minimization and the results will give the worst possible score for Boeing with the assigned color and adjectival rating ranges in the first version of the authors’ model. Then, the adapted version of the following formula will be solved two more times, once for maximization and once for minimization, to reach the results for possible best/worst scenario overall scores for Airbus.

In the model, all the subfactors that are assigned with color and adjectival ratings will be the decision variables. The factors and subfactors, those get specific numerical ratings like IFARA and life cycle cost, will not be included in the model as decision variables. The objective function will be an overall score function that consists of all subfactor ratings and their weights, and the constraints will be the max and min values for each subfactor with color and adjectival ratings. For example, for KSR, decision variable x_1 can get any value between 76 and 100 (including 76 and 100). Since all the decision variables will be in a positive number range, there will not be a non-negativity constraint (redundant constraint-this constraint does not add any value to the model). Also, the model will be solved as a linear model.

MODEL(S) FOR BEST/WORST RATINGS WITHIN COLOR RANGES
(FOR BOEING IN VERSION 1)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) rating.
x_2 : MC subfactor System Integration and Software (SIS) rating.
x_3 : MC subfactor Product Support (PS) rating.
x_4 : MC subfactor Program Management (PM) rating.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) rating.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) rating.
x_7 : PR subfactor System Integration and Software (SIS) rating.
x_8 : PR subfactor Product Support (PS) rating.
x_9 : PR subfactor Program Management (PM) rating.
x_{10} : Cost/Price subfactor Cost Risk (CR) rating.
x_{11} : Past Performance (PP) rating.

Objective Function (Linear Model):

Maximize *or* *Minimize* *Overall Score* = $(0.3\, x_1 + 0.25\, x_2 + 0.2\, x_3 + 0.15\, x_4 + 0.1\, x_5)\, 0.25 +$
$(0.35\, x_6 + 0.3\, x_7 + 0.20\, x_8 + 0.15\, x_9)\, 0.25 +$
$0.25\, x_{11} + 0.125 * 83.2 +$
$(0.40\, x_{10} + 0.60 * 39.12)\, 0.125$

Constraints:

****
For Mission Capability;
$x_1 >= 76$ and $x_1 <=100$ (Subfactor KSR is within blue color rating range)
$x_2 >= 51$ and $x_2 <=75$ (Subfactor SIS is within green color rating range)
$x_3 >= 76$ and $x_3 <=100$ (Subfactor PS is within blue color rating range)
$x_4 >= 51$ and $x_4 <=75$ (Subfactor PM is within green color rating range)
$x_5 >= 67$ and $x_5 <=100$ (Subfactor TMD is within green color rating range)
****
For Proposal Risk;
$x_6 >= 67$ and $x_6 <=100$ (Subfactor KSR is within low adjectival rating range)
$x_7 >= 34$ and $x_7 <=66$ (Subfactor SIS is within moderate adjectival rating range)
$x_8 >= 67$ and $x_8 <=100$ (Subfactor PS is within low adjectival rating range)
$x_9 >= 67$ and $x_9 <=100$ (Subfactor PM is within low adjectival rating range)
****
For Cost/Price;
$x_{10} >= 34$ and $x_{10} <=66$ (CR is within moderate adjectival rating range)
****
For Past Performance;
$x_{11} >= 51$ and $x_{11} <=66$ (PP is within satisfactory adjectival rating range)

To solve the model, Microsoft Excel 2003's Solver tool was used and a snapshot of the spreadsheet is presented in the Appendix section of this study.

The model above is adapted to Airbus by changing the IFARA rating from 83.2 to 92.0 and the life cycle cost (LCC) rating from 39.12 to 39.80 in the objective function for overall score (because these results are evaluated directly as numerical, they are placed as constant values in the model). Also, changing the ranges for x_{10} (cost risk subfactor) is necessary, because Airbus received a 'low' adjectival rating instead of a 'moderate' rating (Boeing's CR rating) for this subfactor. The new range for x_{10} is 67 to 100 instead of 34 to 66. The model formulation for Airbus is also presented in the Appendix section of this study.

As expected in the solution of the models, while solving for maximization, all the ratings (decision variables) got the highest possible points in their range, and while solving for minimization, all the ratings got the lowest possible points in their range. For example, for mission capability subfactor KSR, Boeing originally received a blue color rating which ranges from 76 to 100 on a 100 scale. When solving for maximization, the authors' model assigned 100 points as the rating for this subfactor, and when solving for minimization, the model assigned 76 points.

The overall scores for Boeing are 78.084 as the maximum and 58.334 as the minimum. For Airbus, the scores are 80.935 as the maximum and 61.135 as the minimum. The ranges for max/min overall scores are 19.75 for Boeing and 19.80 for Airbus. Airbus's max/min scores are both almost 2.80 point higher than Boeing's scores, but their scores are overlapping for 16.95 points. These results are also presented in Table 31.

VERSION 1	BOEING	AIRBUS	DIFFERENCE OF BOEING/AIRBUS
MAX	78.084	80.935	2.851
MIN	58.334	61.135	2.801
RANGE	19.75	19.8	

Table 31. Summary Results Table for Sensitivity Analysis Version One.

The sensitivity of the overall scores for both alternatives is very similar. This is because of the fact that while using color and adjectival rating methods for evaluation, the scores for the two alternatives are very similar. There are just three differences - one in the IFARA, one in the LCC, and one in the cost risk rating. Only three out of the thirteen criteria that affect the overall score are different and these are only slightly different. In addition, since these three factors are also multiplied by small weights, they make even a smaller difference in the overall score. Another important finding from these results is the high percentage (almost 85%; 16.95/19.80) of overlap between the ranges of possible points for both alternatives. This overlapping area means that it is possible for either alternative to win the contract whenever the overall scores for both are in this overlapping range.

C. SECOND SENSITIVITY ANALYSIS

For the second part of the sensitivity analysis, the authors will follow the same methodology as the sensitivity analysis in the first part and apply it to the second model. The authors will examine the results of the analysis to understand the effects of color rating ranges on the overall scores. They will again keep the color rating ranges as constant and will change the numerical ratings that are equivalent of those color ratings in the possible rating ranges. In this part, because the authors will be working on their second version, they will not use some of the color and adjectival ratings that were effective in the first model (like red in the color ratings, 'high' in the risk ratings and 'no confidence' in the performance ratings), so the color and adjectival rating ranges will be changed.

The research question is again “How sensitive is the overall WSM score to different numerical ratings within each color range (with a diminished number of color and adjectival ratings)?” This will again give the authors the best and the worst overall score that each company could get using the WSM model of their study (while keeping numerical ratings within color ranges for assigned colors). Then, the authors will also examine the effects of diminishing the effective number of color and adjectival ratings. They will calculate the best and worst overall score in the same way, that is a maximization model for the objective function for the best overall score and a minimization model for the objective function for the worst overall score. Each (max and min) model will be implemented twice, one for Boeing and one for Airbus.

The formulation for Boeing in the second part of the sensitivity analysis will have the same decision variables, a very similar objective function (changes are highlighted), and very similar constraints. The only part that will be different from the formulation for Boeing in version one is the ranges that are the numbers in the right-hand side of the equations for constraints. The new objective function and the new constraints with the new ranges as the right-hand side values of the equations are as follows:

<u>Objective Function:</u>

Maximize *or* *Minimize*

$$\textit{Overall Score} = (0.3\,x_1 + 0.25\,x_2 + 0.2\,x_3 + 0.15\,x_4 + 0.1\,x_5)\,0.25 + (0.35\,x_6 + 0.3\,x_7 + 0.20\,x_8 + 0.15\,x_9)\,0.25 + 0.25\,x_{11} + 0.125 * 79 + (0.40\,x_{10} + 0.60 * 39.12)\,0.125$$

<u>Constraints:</u>

****

For Mission Capability;

$x_1 >= 66$ and $x_1 <=100$ (Subfactor KSR is within blue color rating range)
$x_2 >= 26$ and $x_2 <=65$ (Subfactor SIS is within green color rating range)
$x_3 >= 66$ and $x_3 <=100$ (Subfactor PS is within blue color rating range)
$x_4 >= 26$ and $x_4 <=65$ (Subfactor PM is within green color rating range)
$x_5 >= 61$ and $x_5 <=100$ (Subfactor TMD is within green color rating range)

****

For Proposal Risk;

$x_6 >= 61$ and $x_6 <=100$ (Subfactor KSR is within low adjectival rating range)
$x_7 >= 0$ and $x_7 <=60$ (Subfactor SIS is within moderate adjectival rating range)
$x_8 >= 61$ and $x_8 <=100$ (Subfactor PS is within low adjectival rating range)
$x_9 >= 61$ and $x_9 <=100$ (Subfactor PM is within low adjectival rating range)

****

For Cost/Price;

$x_{10} >= 0$ and $x_{10} <=60$ (CR is within moderate adjectival rating range)

****

For Past Performance;

$x_{11} >= 31$ and $x_{11} <=60$ (PP is within satisfactory adjectival rating range)

With some little changes, this formula is adapted to Airbus to be able to do the same analysis. The model will be solved twice, once for maximization and once for minimization, to reach the results for possible best/worst scenario overall scores for Boeing and Airbus.

To solve the model, Microsoft Excel 2003's Solver tool is used and a snapshot of the spreadsheet is also presented in the Appendix section of this study.

The model in the second sensitivity analysis is adapted to Airbus by changing the IFARA rating from 79 to 90 and the life cycle cost (LCC) rating from 39.12 to 39.80 in the objective function for overall score (since these results are evaluated directly as numerical, they are placed as constant values in the model). Also, changing the ranges for x_{10} (cost risk subfactor) is necessary, because Airbus received a 'low' adjectival rating instead of a 'moderate' rating (Boeing's CR rating) for this subfactor. The new range for x_{10} is 61 to 100 instead of 0 to 60. The model formulation for Airbus is also presented in the Appendix section of this study.

While solving for maximization, all the ratings (decision variables) got the highest possible points in their range and while solving for minimization, all the ratings got the lowest possible points in their range.

The overall scores for Boeing are 74.309 as the maximum and 43.609 as the minimum. For Airbus, the scores are 77.735 as the maximum and 48.085 as the minimum. The ranges for max/min overall scores are 30.70 for Boeing and 29.65 for Airbus. The max/min scores for Airbus are both almost 4 point higher than Boeing's scores, but their scores are overlapping for 26.22 points. These results are also presented in Table 32.

VERSION 2	BOEING	AIRBUS	DIFFERENCE OF BOEING/AIRBUS
MAX	74.309	77.735	3.426
MIN	43.609	48.085	4.476
RANGE	30.7	29.65	

Table 32. Summary Results Table for Sensitivity Analysis Version Two.

The sensitivity of overall scores for both alternatives is very similar. This is because while using the color and adjectival rating methods for evaluation, the scores for the two alternatives are very similar. There are just three differences - one in the IFARA, one in the LCC, and one in the cost risk rating. Only three out of the thirteen criteria that are affecting the overall score are different, and these are only slightly different. In addition, since these three factors are also multiplied by small weights, they make an even smaller difference in the overall score. Another important finding from these results is the high percentage (almost 85%; 26.22/30.7) of overlap between the ranges of possible points for both alternatives. This overlapping area means that it is possible for both alternatives to win the contract whenever the overall scores for both are in this overlapping range. Logically, fewer ranges (rating groups) should cause a larger overlap region, supporting the notion that the less sensitive the method, the more likely it could undervalue small differences. Since the model's second version had a smaller number of color and adjectival ratings, the evaluation results become even less sensitive to the small differences.

D. THIRD SENSITIVITY ANALYSIS

For the third part of the sensitivity analysis, the weights that the authors have used to reflect the relative importance of factors and subfactors will be changed, while keeping original model ratings (version 1 of the model) as constant, to analyze the effects of weights on results. In this analysis part, all the weights (for factors and subfactors) will be changed to analyze the effects on overall scores. The authors' model for the third part of the sensitivity analysis will be solved for maximization and minimization to understand the effective change range for weights. The effects of weight change will be analyzed for each alternative four times, which are the following: weights for maximum overall score in the color rating method, weights for minimum overall score in the color rating method, weights for maximum overall score in the WSM rating method, and weights for minimum overall score in the WSM rating method. These four analyses will be done for each alternative separately and the formulation will have small changes for each iteration.

In the model, all the factor and subfactor weights will be the decision variables. The objective function will be an overall score function that consists of all subfactor ratings and their weights, and the constraints will be the relative importance of subfactors and factors with equality of factor/subfactor weight totals to one for each factor/subfactor level. Since all the decision variables will be in a positive number range, there will not be a non-negativity constraint (redundant constraint-this constraint does not add any value to the model). Also, the model will be solved as a non-linear model.

MODEL(S) FOR BEST/WORST RATINGS FOR WEIGHT CHANGES (FOR BOEING FOR COLOR RATING METHOD IN VERSION 3)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) weight.
x_2 : MC subfactor System Integration and Software (SIS) weight.
x_3 : MC subfactor Product Support (PS) weight.
x_4 : MC subfactor Program Management (PM) weight.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) weight.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) weight.
x_7 : PR subfactor System Integration and Software (SIS) weight.
x_8 : PR subfactor Product Support (PS) weight.
x_9 : PR subfactor Program Management (PM) weight.
x_{10} : Cost/Price subfactor Life Cycle Cost (LCC) weight.
x_{11} : Cost/Price subfactor Cost Risk (CR) weight.
x_{12} : Mission Capability, Proposal Risk and Past Performance factors' weight.
x_{13} : Cost/Price and IFARA factors' weight.

Objective Function (Non-linear Model):

Maximize or *Minimize* *Overall Score* $= [(87.5\, x_1 + 62.5\, x_2 + 87.5\, x_3 + 62.5\, x_4 + 83.3\, x_5)]\, x_{12} + [(83.3\, x_6 + 50\, x_7 + 83.3\, x_8 + 83.3\, x_9)]\, x_{12} + 58.35\, x_{12} + 83.2\, x_{13} + (50\, x_{11} + 39.12\, x_{10})\, x_{13}$

Constraints:
****
For Mission Capability;

$x_1 > x_2$	(KSR is more important than SIS)
$x_2 > x_3$	(SIS is more important than PS)
$x_3 > x_4$	(PS is more important than PM)
$x_4 > x_5$	(PM is more important than TMD)
$x_5 > 0$	(all of the weights are bigger than 0)
$x_1 + x_2 + x_3 + x_4 + x_5 = 1$	(total of weights are equal to 1)

****

For Proposal Risk;

$x_6 > x_7$ (KSR is more important than SIS)

$x_7 > x_8$ (SIS is more important than PS)

$x_8 > x_9$ (PS is more important than PM)

$x_9 > 0$ (all of the weights are bigger than 0)

$x_6 + x_7 + x_8 + x_9 = 1$ (total of weights are equal to 1)

****

For Cost/Price;

$x_{10} > x_{11}$ (LCC is more important than CR)

$x_{11} > 0$ (all of the weights are bigger than 0)

$x_{10} + x_{11} = 1$ (total of weights are equal to 1)

****

For Factor Level;

$x_{12} > x_{13}$ (MC,PR and PP are more important than CR and IFARA)

$x_{13} > 0$ (all of the weights are bigger than 0)

$3\,x_{12} + 2\,x_{13} = 1$ (total of weights are equal to 1)

The formulation above is the base formulation for the third part of the sensitivity analysis. It is the formulation for Boeing's color rating in version one. In this analysis part, the model is no longer linear because of the multiplication of some decision variables which causes the authors' model to become a non-linear model (MC, PR and CR subfactor weights are multiplied by factor level weights and then the model becomes non-linear).

In all of the iterations of the model, the decision variables and the constraints will not be changed. The only differences will be made in the objective function and it will be the change of some constant values for the color rating part for Airbus (the differences between the models for Boeing and Airbus are highlighted below), and the change of all the constant values for the WSM rating method (for Boeing and Airbus). All three objective functions are presented below (not the whole mathematical formulation) and also full and separate versions of the formulations for each iteration can be found in the Appendix section of this study.

To solve the model, Microsoft Excel 2003's Solver tool is used and a snapshot of the spreadsheet is also presented in the Appendix section of this study.

Objective Function for Airbus Color Rating Weights Change Effects:

$$\begin{array}{lll} \textit{Maximize} & \textit{Overall Score} = & [(87.5\, x_1 + 62.5\, x_2 + 87.5\, x_3 + 62.5\, x_4 + 83.3\, x_5)]\, x_{12} + \\ \quad \textit{or} & & [(83.3\, x_6 + 50\, x_7 + 83.3\, x_8 + 83.3\, x_9)]\, x_{12} + \\ \textit{Minimize} & & 58.35\, x_{12} + 92\, x_{13} + (83.3\, x_{11} + 39.8\, x_{10})\, x_{13} \end{array}$$

Objective Function for Boeing Numerical Rating Weights Change Effects:

$$\begin{array}{lll} \textit{Maximize} & \textit{Overall Score} = & [(93\, x_1 + 64\, x_2 + 92\, x_3 + 63\, x_4 + 94\, x_5)]\, x_{12} + \\ \quad \textit{or} & & [(94\, x_6 + 57\, x_7 + 97\, x_8 + 94\, x_9)]\, x_{12} + \\ \textit{Minimize} & & 59\, x_{12} + 83.2\, x_{13} + (58\, x_{11} + 39.12\, x_{10})\, x_{13} \end{array}$$

Objective Function for Airbus Numerical Rating Weights Change Effects:

$$\begin{array}{lll} \textit{Maximize} & \textit{Overall Score} = & [(81\, x_1 + 60\, x_2 + 90\, x_3 + 58\, x_4 + 85\, x_5)]\, x_{12} + \\ \quad \textit{or} & & [(85\, x_6 + 57\, x_7 + 91\, x_8 + 87\, x_9)]\, x_{12} + \\ \textit{Minimize} & & 56\, x_{12} + 92\, x_{13} + (70\, x_{11} + 39.8\, x_{10})\, x_{13} \end{array}$$

After solving all these iterations to analyze the overall score sensitivity to weight change, the overall scores for Boeing are 75.30 as the maximum and 65.04 as the minimum for the color rating method and 80.75 as the maximum and 67.38 as the minimum for the WSM method. The overall scores for Airbus are 75.97 as the maximum and 66.95 as the minimum for the color rating method and 73.44 as the maximum and 66.18 as the minimum for the WSM method. The results are presented in Table 33;

	COLOR MAX	COLOR MIN	WSM MAX	WSM MIN
BOEING	75.30	65.04	80.75	67.38
	ORIGINAL 68.02		ORIGINAL 72.15	
AIRBUS	75.97	66.95	73.44	66.18
	ORIGINAL 70.84		ORIGINAL 70.14	

Table 33. Summary Results Table for Sensitivity Analysis Version Three.

Also, the change range for overall scores, which is due to weight changes, is very similar for Boeing (10.26) and for Airbus (9.03) in the color rating method. However, in the WSM method the change range difference is significant, as it is 13.38 for Boeing and 7.26 for Airbus. Because Boeing's ratings for most of the subfactors are higher than Airbus in WSM method, Boeing is more sensitive to weight changes in WSM method.

These results also show the difference between the color rating method and the WSM method, as the color rating method is less competent than the WSM method to reflect the little changes, the differences in ratings are hide in color ratings and both Boeing and Airbus change ranges become similar.

In this part of the sensitivity analysis, the authors also wanted to analyze the overall scores for a special case. They implemented Boeing's best case scenario weights to calculate the overall score for Airbus in the same scenario. The Microsoft Excel snapshot of this scenario is shown in the Appendix section of this study. For the color rating method, the results were 75.30 for Boeing and 75.56 for Airbus, which means with some cost, cost risk rating and IFARA advantage Airbus won with the color rating model even with Boeing's best scenario weights. For the numerical rating, the results were 80.75 for Boeing and 73.44 for Airbus, which results in a significant advantage for Boeing. Table 34 below summarizes these results.

BOEING'S BEST RESULT RATINGS VS. AIRBUS WITH SAME WEIGHTS		
	COLOR	NUMERICAL
BOEING	75.30	80.75
AIRBUS	75.56	73.44

Table 34. Summary Results Table for Special Case: Boeing's Best Case Scenario.

The authors also implemented the best case scenario weights for Airbus to calculate Boeing's overall score in that scenario. The Microsoft Excel snapshot of this scenario is also shown in the Appendix section of this study. For the color rating method, the results were 71.00 for Boeing and 75.97 for Airbus, which results in a significant advantage for Airbus. For the numerical rating, the results were the same as the previous scenario and both alternatives' best results because the best result weights were the same for both alternatives in the numerical method. A summary of these results is shown in Table 35.

AIRBUS'S BEST RESULT RATINGS VS. BOEING WITH SAME WEIGHTS		
	COLOR	NUMERICAL
BOEING	71.00	80.75
AIRBUS	75.97	73.44

Table 35. Summary Results Table for Special Case: Airbus's Best Case Scenario.

E. CONCLUSIONS

The sensitivity analysis to understand the effects of rating change within color ranges on both versions of the authors' study produced identical results. This is due to the fact that while using color and adjectival rating methods for evaluation, the scores for two alternatives are very similar. There are just three differences - one in the IFARA, one in the LCC, and one in the cost risk rating. Only three out of the thirteen criteria that are affecting the overall score are slightly different. In addition, since these three factors are also multiplied by small weights, they make an even smaller difference in the overall score. Another important finding of the results of rating change within color ranges effects analysis for the two models is the high percentage of overlap between the ranges of possible points for both alternatives. This overlapping area means that it is possible for either alternative to win the contract whenever the overall scores for both are in this overlapping range. Also, the overlapping area allows subjectivity in the evaluation of offeror proposals. The difference between these sensitivity analysis implementations on the two versions of the authors' study is the results of range changes (elimination of some ratings lead to redetermination of ranges). Since the ranges get bigger in the second version, the effects of rating change get bigger as expected and the amount of subjectivity (with growing overlapping ranges) allowed gets increased.

The sensitivity analysis to understand the effects of weight (factor and subfactor weights all together) changes on the overall scores produced interesting results. The change ranges for overall scores were very similar for Boeing and for Airbus in the color rating method. However, in the WSM method the change range difference was significant. These results show how the color rating method is less sensitive than the numerical method (less competent to reflect the little changes).

The authors finished their sensitivity analysis with a special case scenario analysis. Boeing's best case scenario weights implemented to Airbus and results for the color rating method lead to an Airbus award even in Boeing's best case scenario. In that case, it shows that even with higher numerical scores, Boeing will not be able to present its better value (better value than Airbus) under the color rating method. In WSM method, Boeing's best case scenario weights implemented to Airbus lead to a significant overall score advantage for Boeing. Airbus's best case scenario weights implemented to Boeing resulted with significant advantage for Airbus in color rating method, however the results were significantly advantageous for Boeing in WSM method (even in Airbus's best case scenario).

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The source selection phase of government acquisitions involves many interrelated tasks. Even though objective factors and subfactors are used in the source selection phase, subjectivity is inevitable in government contracting. This is because the Federal Acquisition Regulation (FAR) does not provide any clear guidance to evaluate proposals and, thus, the source selection decision is usually made based on some evaluations "conducted using any rating method or a combination of methods, including color or adjectival ratings, numerical weights, and ordinal rankings."[143] Besides, proposals are evaluated by different personnel and conclusions may differ, even for the same factor, significantly.[144] Therefore, considering the high complexity in the nature of government acquisitions, the comparison of proposals and source selection decision involve judgmental evaluations.[145]

Considering the fact that available resources to the government are becoming scarcer, subjectivity should be diminished in contracting and agencies should find ways to get the best value from any procurement. Quantitative methods and information technology tools can be utilized to augment objectivity in source selection decision making.

The aim of this project is to show the effects of the choice of model (method) used, as well as decisions made during the modeling and assessment process. These choices may contrast with the fairness and the best value part of government procurement processes. Fair to whom and best value for whom were the very first questions in the

[143] FAR 15.305.

[144] Cibinic and Nash, *Formation of Government Contracts,* 821.

[145] Templin and Noffsinger, "An Assessment," 38.

authors' minds when they started this project. The authors tried to show the effects of subjectivity involved in the process of selection by using a simplified current real-life program.

The authors chose the USAF's KC-X program as a case study for their research questions. There are some specific reasons for their choice of that program. The authors focused on an Air Force procurement program in which color ratings were used, because in their perspective, the Air Force's color rating is one of the most subjective techniques used in source selection. The authors decided to analyze a program that was popular and current. The authors thought that they could have a variety of comments from different viewpoints. With a current program, they hoped to have more insight information, which was publicly available, about the program. After their initial research on the program, the authors realized that the two alternatives offered very different specifications and capabilities for the same program. This showed the authors the difference of the two offerors' point of view. The authors thought that this program might be a good sample for their study because of the potential effects of the choices made for and during the evaluation. Another factor that made the choice even more interesting for this study was the high potential for the award to be protested. Experts of the defense industry were expecting a protest from the loser. Since the proposed KC-X alternatives have very different strengths in capabilities, results will not easily satisfy the offeror who loses the program award.

The source selection phase in government contracting involves multi-criteria decision making which has to deal with many critical factors such as cost, technical capabilities, and the past performance of contractors. The contracting processes used in government acquisitions have been built to respond to various government procurement needs by evaluating these factors.

In Chapter II an overview of acquisitions, general summary information about acquisition processes was provided. First, contracting methods were discussed and then, the evaluation and selection processes were defined briefly. Since this project focused on the Air Force's color rating method, the Air Force source selection was examined a little deeper on categories of Air Force acquisitions, steps in Air Force source selection, evaluation activities, and award activities.

Chapter III provided an overview of decision-making support techniques, the authors gave some background information about the available techniques to solve a multi-criteria problem since the study case (the Air Force's KC-X program) is a major weapon systems procurement and has more than one criterion to determine while trying to come up with the best value product for the government. Multi-criteria decision analysis (MCDA) offers numerous methodologies and schools of thought for multi-criteria modeling. The approaches vary from very simple ones to extremely complex optimization models.

The authors used the weighted sum method (WSM) in their study. They preferred a technique that was simple to understand by anyone who has no multi-criteria decision making (MCDM) background. WSM is one of the very basic models/techniques used in situations where more than one criterion is involved and the relative importance of each criterion is different from each other. The model's biggest strength is its simplicity in application.

Chapter IV discussed the USAF's KC-X Next Generation Tanker Planes Program, the authors gave some background information about the Air Force's KC-X program. They used this program in their model to show the subjectivity involved in the source selection proposal evaluation part of the Air Force's acquisitions. Introductory information about the program, the requirements of the program, the competition between the two offerors, and lastly some specific information (to roughly compare the two alternatives) about each proposed aircraft were presented in this chapter.

In the KC-X Tanker Replacement Program, which is recently the most significant procurement program in the Air Force, the Air Force used its current source selection method, namely the color rating method, and awarded the contract to the Airbus/Northrop Grumman team. After debriefings were presented, the fact emerged that the ratings of both offerors were almost the same. Consequently, long debates have begun between

Boeing and the Air Force with Boeing filing a protest with the Government Accountability Office (GAO) for review of the award decision. The similar color ratings led to the protest exercised in the KC-X program and in some previous contract awards; therefore in the authors' model this was one of the focus areas.

In Chapter V about model construction, two models that were built within Microsoft Excel were presented in two versions to show the different characteristics of two types of methods that can be used in the source selection phase in government acquisitions. These methods are color rating, which is the current method used by the U.S. Air Force, and the quantitative weighted sum method. The models were established using some data from the Air Force's current KC-X Tanker Replacement Program and proposals of its two offerors, Boeing and Northrop/Airbus. In Chapter VI that discusses the analysis and results, simplified KC-X program data was implemented in these models. Two offerors' color rating data that are provided from publicly available sources were used in the models.

In Chapter VII that presents the sensitivity analysis, the authors investigated how modeling choices might affect the results that were found in the previous chapter. A sensitivity analysis was done to understand the effects and limits of subjectivity in the authors' models. Three different forms of sensitivity analysis were done. In the first two, the numerical ratings for the color and adjectival ratings were changed within their ranges to determine the best/worst possible overall scores for each alternative in the first and second versions of the authors' model. In the third one, the weights were changed, while keeping original model ratings as constant, to analyze the effects of weights on the results.

B. CONCLUSIONS

In the authors' study, with their arbitrary numerical ratings chosen to be within the ranges of the color ratings given in the KC-X program, they were able to show that when they used the USAF's color rating method, Airbus could have won the contract, but when they used the WSM method, Boeing could have won the contract. The implication under these results is that when there are small but important differences between offerors, the color rating method is potentially incompetent to reflect those differences. However, the quantitative weighted sum method is capable of handling those little details and providing more accurate results.

As explained previously, in the authors' models, version two differed from version one based on some changes to the color/adjectival ratings used and their numerical ranges. Initially, the color/adjectival ratings that reflected the lowest values for factors/subfactors were eliminated and then, the numerical ranges to which the color and adjectival ratings were related to were extended or narrowed. The arbitrarily chosen numerical ratings were then adjusted so that they still fell within the ranges of the color ratings given within the KC-X program. The second version of the authors' model, which suggested a different way to evaluate both offerors, produced the same significant result as was obtained in the first version.

This part of the study supported the authors' argument that the quantitative weighted sum method is more competent than the color rating method in reflecting the little but important differences between offerors.

In Chapter VII concerning sensitivity analysis, first the authors investigated how modeling choices might affect previous results that they found. They performed a sensitivity analysis to answer the research question: “How sensitive are the overall WSM scores to different numerical ratings within each color range?” While keeping the color rating ranges constant, the authors varied the numerical ratings within the given ranges for the color rating that was assigned to see how much better or worse the overall score could be while still corresponding to the same color rating.

The sensitivity of overall scores for both alternatives was very similar. This is because while using color and adjectival rating method for evaluation, the scores for two alternatives were very similar. There were just three differences - one in the IFARA, one in the LCC, and one in cost risk rating. Only three out of the thirteen criteria that were affecting the overall score were different, albeit only slightly different. In addition, since these three factors were also multiplied by small weights, they made an even smaller difference in the overall score. Another important finding of these results is the high percentage of overlap between the ranges of possible final scores for both alternatives. This overlapping area means that it is possible for either alternative to win the contract whenever the overall scores for both are in this overlapping range.

Secondly, the sensitivity analysis used in the first part was used in the second model as well. The authors examined the results of the analysis to understand the effects of the choice of color rating ranges on the overall scores. The research question here was "How sensitive is the overall numerical score to different numerical ratings within each color range with a diminished number of color and adjectival ratings with appropriately adjusted color rating ranges?"

Similarly with the first sensitivity analysis, the overall score sensitivities for both alternatives were very similar. It is because while using the color and adjectival rating method for evaluation, the scores for the two alternatives were very similar and also with the multiplier effect of weights these differences were getting less significant. Another important finding of these results is the high percentage of overlap between the ranges of possible final scores for both alternatives. This overlapping area means that it is possible for either alternative to win the contract whenever the overall scores for both are in this overlapping range. Logically, fewer ranges (rating groups) should cause a larger overlap region, supporting the notion that the less sensitive the method, the more likely it could undervalue small differences. Since the authors' second version of their model had less number of color and adjectival ratings, the evaluation results became even less sensitive to the small differences.

The sensitivity analysis to understand the effects of rating change within the color range on both versions of the authors' study produced very similar results, namely a high percentage of overlap for final score ranges for both alternatives in both versions. The overlapping area means that it is possible for both alternatives to win the contract whenever the overall scores for both are in this overlapping range. The overlapping areabrings about the subjectivity issue to the evaluation of offeror proposals, because as the ranges got bigger in the second version, the effects of the rating change got bigger as expected and the subjectivity (with a growing overlapping range) involved increased as well.

In the third part of the authors' sensitivity analysis, the weights were changed in both the color rating method and the WSM method, while the original model ratings were kept constant, to analyze the effects of weights on the results. In this analysis part, all the weights (for factors and subfactors) were varied to analyze the effects on overall scores. The sensitivity analysis to understand the effects of weight changes (including all factor and subfactor weights) on the overall scores produced interesting results. The range of changes for overall scores was very similar for Boeing and for Airbus in the color rating method. However, in the WSM method the change range difference was significant. These results were more substantiating data for the authors' study to show how the color rating method is less sensitive than the WSM method (less competent to reflect the small, but potentially important differences between alternatives).

In the last part of the sensitivity analysis, the authors also wanted to analyze the overall scores for two special cases. First, they solved for the weights that would give Boeing the best possible overall score. Then, they implemented Boeing's best case scenario weights to calculate the overall score for Airbus in the same scenario. For the color rating method, Airbus won even with Boeing's best scenario weights. For the WSM rating, the results were significantly better for Boeing. The authors also solved for Airbus's best case scenario weights too and used them to calculate Boeing's overall score in the same scenario. The results were very similar to the first special case, as Airbus won in with the color rating method even with a significant advantage. However, for the WSM method Boeing was far better than Airbus.

It is necessary to remember that in this study, the authors had only the color ratings that were available, and therefore, they converted these color ratings to numbers and arbitrarily chose the ratings used in the WSM model to fall within the same color rating ranges. All the results came from the models where the authors used those arbitrary numbers. The purpose of the study was not to say who should have won the KC-X contract. The actual evaluation of proposals was done by a team consisting of many experts and the evaluation period was almost a year even for such a big team (the authors did not have enough information, time, and intent to do the same evaluation in a better way). The authors simply wanted to show that the contract resulted in a different winner by using numbers and the WSM method instead of the color and adjectival ratings method.

The color rating method was not sensitive enough for little differences in the evaluation ratings. These little differences in each factor or subfactor ratings may be in favor of one alternative. Thus, by using the color rating method one may eliminate all those little changes and consider both alternatives with the same color ratings and then possibly choose the wrong one (not the one that gives the best value).

The authors' sensitivity analysis also showed that the color rating range determination is very critical because the effects of these ranges on the results are pretty significant. The effects of color rating ranges are much higher than the effects of the weights of factors and subfactors. Additionally, the first (color rating range analysis on version one) and second sensitivity (same analysis on version two) showed the authors that with the less number of ratings they increased the ranges and as a result they made the color rating method even less sensitive to little differences.

The third part of the sensitivity analysis results showed the effects of weights on overall scores. As mentioned before, the effects of weights were not as big as the effects of the color and adjectival rating ranges. One of the biggest reasons for the weights being less effective was because the verbal explanations of the relationships between these weights were given precisely in the RFP, so there was not much flexibility to change the weights.

In conclusion, although the color rating method is currently the method for the Air Force, it is not necessarily competent whenever the scores of the proposed options are close. In some cases like the one the authors analyzed, the color rating method may eliminate some of the small differences (however, when aggregated these small differences may affect the overall score significantly) and may lead the decision maker in the wrong direction. The government has different responsibilities than the private sector, like being fair all the time. So, when seeking the best value, the government should make a fair evaluation of the proposals and explain the logic of their decision. With the color rating method, the authors think that the government in some cases may not be able to make the evaluation fairly. This will not only lead to some trust issues but also lead to protests from the losers. With the protests, even the most important programs can be suspended and a significant amount of money can be spent in resolving the issues.

C. RECOMMENDATIONS AND FUTURE RESEARCH

The government's responsibility is not only managing its programs successfully from a business stand point; government also has some other responsibilities like socio-economic responsibilities. The government must act fairly in all contract actions and making a fair evaluation of competing proposals is one of these responsibilities. Therefore, the government must be consistent in its evaluation of the proposals process and precise while explaining its requirements and methods for the evaluations. The color rating method is not a very competent method to obtain the best value, but it is clear that it gives the evaluator some space for flexibility when determining the best value for the government. The color rating method may end up eliminating the individual evaluation differences and establish a consensus on the score for individual factors and subfactors, but it is not competent enough to be used as the main method to determine which offeror will be awarded the contract. Although it seems that the color rating method is less subjective since it eliminates individual evaluation differences, it may come up with subjective results when used as the main method for evaluation of the proposals because of the elimination of small differences and their aggregate effects to the overall score. When the color rating results are similar, which is very likely to happen, it is hard to justify the choice that has been made as a government. Whenever the offerors are not satisfied with the results, and especially when they feel the results did not show a clear winner (the lack of clarity in the evaluation), they are very likely to protest the award, which leads to suspension of the program until all the protests are resolved.

Instead of using a purely numerical model such as the weighted sum method, the color rating method can be developed again with an increased number of color and adjectival ratings instead of four or five ratings in order to increase its sensitivity to small differences. A more extensive numerical study could be performed to develop a recommendation for how many colors to use (how sensitive one wants the color rating method to small differences) and how to define the conditions under each given color (similar to what is in place now for the red-yellow-green-blue color scheme).

Another study could be done to understand the relationship between the color rating method and protests. This study could explore whether the U.S. Air Force was being protested more or less before they started using the color rating method and also determine whether protests under the color rating method are more common when the competing proposals were given similar color ratings.

APPENDIX

Example Snapshot of Version One Color Rating Spreadsheet

MISSION CAPABILITY SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	GREEN	0.30	62.5	18.75
SIS	YELLOW	0.25	37.5	9.375
PS	RED	0.20	12.5	2.5
PM	BLUE	0.15	87.5	13.125
TMD	GREEN	0.10	83.3	8.33
				52.08

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	107	0.60	60	36
RISK	LOW	0.40	83.3	33.32
				69.32

IFARA	RATING
1.36	48.8
	48.8

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.35	83.3	29.155
SIS	MODERATE	0.30	50	15
PS	LOW	0.20	83.3	16.66
PM	HIGH	0.15	16.7	2.505
				63.32

PAST PERFORMANCE	RATING
SATISFACTORY	58.35
	58.35

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	52.08	13.02
Proposal Risk	0.250	63.32	15.83
Past Performance	0.250	58.35	14.5875
Cost/Price	0.125	69.32	8.665
IFARA	0.125	48.80	6.1
		OVERALL OFFEROR RATING:	58.2025

Example Snapshot of Version One Weighted Sum Method Spreadsheet

MISSION CAPABILITY SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	72	0.30	21.6
SIS	41	0.25	10.25
PS	22	0.20	4.4
PM	91	0.15	13.65
TMD	78	0.10	7.8
			57.7

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	107	0.60	60	36
RISK	89	0.40	89	35.6
				71.6

IFARA	RATING
1.36	48.8
	48.8

PROPOSAL RISK SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	71	0.35	24.85
SIS	42	0.30	12.6
PS	88	0.20	17.6
PM	26	0.15	3.9
			58.95

PAST PERFORMANCE	RATING
SATISFACTORY	62
	62

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	57.70	14.425
Proposal Risk	0.250	58.95	14.7375
Past Performance	0.250	62.00	15.5
Cost/Price	0.125	71.60	8.95
IFARA	0.125	48.80	6.1
		OVERALL OFFEROR RATING:	59.7125

The Snapshot of Version One Color Rating Method Spreadsheet for Boeing

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.30	87.5	26.250
SIS	GREEN	0.25	62.5	15.625
PS	BLUE	0.20	87.5	17.500
PM	GREEN	0.15	62.5	9.375
TMD	GREEN	0.10	83.3	8.330
				77.080

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.60	39.12	23.472
RISK	MODERATE	0.40	50	20.000
				43.472

IFARA	RATING
1.79	83.2
	83.2

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.35	83.3	29.155
SIS	MODERATE	0.30	50.0	15.000
PS	LOW	0.20	83.3	16.660
PM	LOW	0.15	83.3	12.495
				73.310

PAST PERFORMANCE	RATING
SATISFACTORY	58.35
	58.35

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	77.08	19.270
Proposal Risk	0.250	73.31	18.328
Past Performance	0.250	58.35	14.588
Cost/Price	0.125	43.47	5.434
IFARA	0.125	83.20	10.400
		OVERALL OFFEROR RATING:	68.019

The Snapshot of Version One Color Rating Method Spreadsheet for Airbus

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.30	87.5	26.250
SIS	GREEN	0.25	62.5	15.625
PS	BLUE	0.20	87.5	17.500
PM	GREEN	0.15	62.5	9.375
TMD	GREEN	0.10	83.3	8.330
				77.080

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.01	0.60	39.8	23.88
RISK	LOW	0.40	83.3	33.32
				57.20

IFARA	RATING
1.9	92
	92

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.35	83.3	29.155
SIS	MODERATE	0.30	50.0	15.000
PS	LOW	0.20	83.3	16.660
PM	LOW	0.15	83.3	12.495
				73.310

PAST PERFORMANCE	RATING
SATISFACTORY	58.35
	58.35

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	77.08	19.270
Proposal Risk	0.250	73.31	18.328
Past Performance	0.250	58.35	14.588
Cost/Price	0.125	57.20	7.150
IFARA	0.125	92.00	11.500
	OVERALL OFFEROR RATING:		70.835

The Snapshot of Version One Weighted Sum Method Spreadsheet for Boeing

MISSION CAPABILITY SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	93	0.30	27.90
SIS	64	0.25	16.00
PS	92	0.20	18.40
PM	63	0.15	9.45
TMD	94	0.10	9.40
			81.15

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.60	39.12	23.472
RISK	58	0.40	58.00	23.200
				46.672

IFARA	RATING
1.79	83.2
	83.2

PROPOSAL RISK SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	94	0.35	32.9
SIS	57	0.30	17.1
PS	97	0.20	19.4
PM	94	0.15	14.1
			83.5

PAST PERFORMANCE	RATING
SATISFACTORY	59
	59

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	81.15	20.288
Proposal Risk	0.250	83.50	20.875
Past Performance	0.250	59.00	14.750
Cost/Price	0.125	46.67	5.834
IFARA	0.125	83.20	10.400
OVERALL OFFEROR RATING:			72.147

The Snapshot of Version One Weighted Sum Method Spreadsheet for Airbus

MISSION CAPABILITY SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	81	0.30	24.3
SIS	60	0.25	15.0
PS	90	0.20	18.0
PM	58	0.15	8.7
TMD	85	0.10	8.5
			74.5

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.01	0.60	39.8	23.88
RISK	70	0.40	70.0	28.00
				51.88

IFARA	RATING
1.9	92
	92

PROPOSAL RISK SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	85	0.35	29.75
SIS	57	0.30	17.10
PS	91	0.20	18.20
PM	87	0.15	13.05
			78.10

PAST PERFORMANCE	RATING
SATISFACTORY	56
	56

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	74.50	18.625
Proposal Risk	0.250	78.10	19.525
Past Performance	0.250	56.00	14.000
Cost/Price	0.125	51.88	6.485
IFARA	0.125	92.00	11.500
		OVERALL OFFEROR RATING:	70.135

The Comparison Chart Showing Both Offerors' Ratings Using Both Methods in Version One

BOEING			AIRBUS		
COLOR		WSM	COLOR		WSM
MISSION CAPABILITY			MISSION CAPABILITY		
KSR	BLUE	93	KSR	BLUE	81
SIS	GREEN	64	SIS	GREEN	60
PS	BLUE	92	PS	BLUE	90
PM	GREEN	63	PM	GREEN	58
TMD	GREEN	94	TMD	GREEN	85
PROPOSAL RISK			PROPOSAL RISK		
KSR	LOW	94	KSR	LOW	85
SIS	MODERATE	57	SIS	MODERATE	57
PS	LOW	97	PS	LOW	91
PM	LOW	94	PM	LOW	87
PAST PERFORMANCE			PAST PERFORMANCE		
SATISFACTORY		59	SATISFACTORY		56
COST/PRICE			COST/PRICE		
COST	108.044	108.044	COST	108.01	108.1
RISK	MODERATE	58	RISK	LOW	70
IFARA			IFARA		
1.79		1.79	1.9		1.9
68.019		**72.147**	**70.835**		**70.135**

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The Snapshot of Version Two Color Rating Method Spreadsheet for Boeing

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.30	82.5	24.75
SIS	GREEN	0.25	45.0	11.25
PS	BLUE	0.20	82.5	16.50
PM	GREEN	0.15	45.0	6.75
TMD	GREEN	0.10	80.0	8.00
				67.25

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.60	39.12	23.472
RISK	MODERATE	0.40	30.00	12.000
				35.472

IFARA	RATING
1.79	79
	79

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.35	80	28
SIS	MODERATE	0.30	30	9
PS	LOW	0.20	80	16
PM	LOW	0.15	80	12
				65

PAST PERFORMANCE	RATING
SATISFACTORY	45
	45

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	67.250	16.813
Proposal Risk	0.250	65.000	16.250
Past Performance	0.250	45.000	11.250
Cost/Price	0.125	35.472	4.434
IFARA	0.125	79.000	9.875
		OVERALL OFFEROR RATING:	58.622

The Snapshot of Version Two Color Rating Method Spreadsheet for Airbus

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.30	82.5	24.75
SIS	GREEN	0.25	45.0	11.25
PS	BLUE	0.20	82.5	16.50
PM	GREEN	0.15	45.0	6.75
TMD	GREEN	0.10	80.0	8.00
				67.25

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.01	0.60	39.80	23.88
RISK	LOW	0.40	80.00	32.00
				55.88

IFARA	RATING
1.9	90
	90

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.35	80	28
SIS	MODERATE	0.30	30	9
PS	LOW	0.20	80	16
PM	LOW	0.15	80	12
				65

PAST PERFORMANCE	RATING
SATISFACTORY	45
	45

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	67.25	16.813
Proposal Risk	0.250	65.00	16.250
Past Performance	0.250	45.00	11.250
Cost/Price	0.125	55.88	6.985
IFARA	0.125	90.00	11.250
	OVERALL OFFEROR RATING:		62.548

The Snapshot of Version Two Weighted Sum Method Spreadsheet for Boeing

MISSION CAPABILITY SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	93	0.30	27.90
SIS	64	0.25	16.00
PS	92	0.20	18.40
PM	63	0.15	9.45
TMD	94	0.10	9.40
			81.15

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.60	39.12	23.472
RISK	58	0.40	58.00	23.200
				46.672

IFARA	RATING
1.79	79
	79

PROPOSAL RISK SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	94	0.35	32.9
SIS	57	0.30	17.1
PS	97	0.20	19.4
PM	94	0.15	14.1
			83.5

PAST PERFORMANCE	RATING
59	59

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	81.15	20.288
Proposal Risk	0.250	83.50	20.875
Past Performance	0.250	59.00	14.750
Cost/Price	0.125	46.67	5.834
IFARA	0.125	79.00	9.875
		OVERALL OFFEROR RATING:	71.622

The Snapshot of Version Two Weighted Sum Method Spreadsheet for Airbus

MISSION CAPABILITY SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	81	0.30	24.3
SIS	60	0.25	15.0
PS	90	0.20	18.0
PM	58	0.15	8.7
TMD	85	0.10	8.5
			74.5

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.01	0.60	39.8	23.88
RISK	70	0.40	70.0	28.00
				51.88

IFARA	RATING
1.9	90
	90

PROPOSAL RISK SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	85	0.35	29.75
SIS	57	0.30	17.10
PS	91	0.20	18.20
PM	87	0.15	13.05
			78.10

PAST PERFORMANCE	RATING
56	56

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	74.50	18.625
Proposal Risk	0.250	78.10	19.525
Past Performance	0.250	56.00	14.000
Cost/Price	0.125	51.88	6.485
IFARA	0.125	90.00	11.250
		OVERALL OFFEROR RATING:	69.885

The Comparison Chart Showing Both Offerors' Ratings Using Both Methods in Version Two

BOEING			AIRBUS		
COLOR		WSM	COLOR		WSM
MISSION CAPABILITY			**MISSION CAPABILITY**		
KSR	BLUE	93	KSR	BLUE	81
SIS	GREEN	64	SIS	GREEN	60
PS	BLUE	92	PS	BLUE	90
PM	GREEN	63	PM	GREEN	58
TMD	GREEN	94	TMD	GREEN	85
PROPOSAL RISK			**PROPOSAL RISK**		
KSR	LOW	94	KSR	LOW	85
SIS	MODERATE	57	SIS	MODERATE	57
PS	LOW	97	PS	LOW	91
PM	LOW	94	PM	LOW	87
PAST PERFORMANCE			**PAST PERFORMANCE**		
SATISFACTORY		59	SATISFACTORY		56
COST/PRICE			**COST/PRICE**		
COST	108.044	108.044	COST	108.01	108.1
RISK	MODERATE	58	RISK	LOW	70
IFARA			**IFARA**		
1.79		1.79	1.9		1.9
58.622		**71.622**	**62.548**		**69.885**

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Sensitivity Analysis Model for Best/Worst Ratings within Color Ranges
(For Boeing in Version 1)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) rating.
x_2 : MC subfactor System Integration and Software (SIS) rating.
x_3 : MC subfactor Product Support (PS) rating.
x_4 : MC subfactor Program Management (PM) rating.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) rating.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) rating.
x_7 : PR subfactor System Integration and Software (SIS) rating.
x_8 : PR subfactor Product Support (PS) rating.
x_9 : PR subfactor Program Management (PM) rating.
x_{10} : Cost/Price subfactor Cost Risk (CR) rating.
x_{11} : Past Performance (PP) rating.

Objective Function (Linear Model):

Maximize *or* *Minimize* *Overall Score* = $(0.3\,x_1 + 0.25\,x_2 + 0.2\,x_3 + 0.15\,x_4 + 0.1\,x_5)\,0.25 +$
$(0.35\,x_6 + 0.3\,x_7 + 0.20\,x_8 + 0.15\,x_9)\,0.25 +$
$0.25\,x_{11} + 0.125 * 83.2 +$
$(0.40\,x_{10} + 0.60 * 39.12)\,0.125$

Constraints:

****
For Mission Capability;
$x_1 >= 76$ and $x_1 <=100$ (Subfactor KSR is within blue color rating range)
$x_2 >= 51$ and $x_2 <=75$ (Subfactor SIS is within green color rating range)
$x_3 >= 76$ and $x_3 <=100$ (Subfactor PS is within blue color rating range)
$x_4 >= 51$ and $x_4 <=75$ (Subfactor PM is within green color rating range)
$x_5 >= 67$ and $x_5 <=100$ (Subfactor TMD is within green color rating range)
****
For Proposal Risk;
$x_6 >= 67$ and $x_6 <=100$ (Subfactor KSR is within low adjectival rating range)
$x_7 >= 34$ and $x_7 <=66$ (Subfactor SIS is within moderate adjectival rating range)
$x_8 >= 67$ and $x_8 <=100$ (Subfactor PS is within low adjectival rating range)
$x_9 >= 67$ and $x_9 <=100$ (Subfactor PM is within low adjectival rating range)
****
For Cost/Price;
$x_{10} >= 34$ and $x_{10} <=66$ (CR is within moderate adjectival rating range)
****
For Past Performance;
$x_{11} >= 51$ and $x_{11} <=66$ (PP is within satisfactory adjectival rating range)

Sensitivity Analysis Model for Best/Worst Ratings within Color Ranges
(For Airbus in Version 1)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) rating.
x_2 : MC subfactor System Integration and Software (SIS) rating.
x_3 : MC subfactor Product Support (PS) rating.
x_4 : MC subfactor Program Management (PM) rating.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) rating.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) rating.
x_7 : PR subfactor System Integration and Software (SIS) rating.
x_8 : PR subfactor Product Support (PS) rating.
x_9 : PR subfactor Program Management (PM) rating.
x_{10} : Cost/Price subfactor Cost Risk (CR) rating.
x_{11} : Past Performance (PP) rating.

Objective Function (Linear Model):

Maximize *or* *Minimize* *Overall Score* = $(0.3\ x_1 + 0.25\ x_2 + 0.2\ x_3 + 0.15\ x_4 + 0.1\ x_5)\ 0.25 +$
$(0.35\ x_6 + 0.3\ x_7 + 0.20\ x_8 + 0.15\ x_9)\ 0.25 +$
$0.25\ x_{11} + 0.125 * 92 +$
$(0.40\ x_{10} + 0.60 * 39.8)\ 0.125$

Constraints:

****
For Mission Capability;
$x_1 >= 76$ and $x_1 <=100$ (Subfactor KSR is within blue color rating range)
$x_2 >= 51$ and $x_2 <=75$ (Subfactor SIS is within green color rating range)
$x_3 >= 76$ and $x_3 <=100$ (Subfactor PS is within blue color rating range)
$x_4 >= 51$ and $x_4 <=75$ (Subfactor PM is within green color rating range)
$x_5 >= 67$ and $x_5 <=100$ (Subfactor TMD is within green color rating range)
****
For Proposal Risk;
$x_6 >= 67$ and $x_6 <=100$ (Subfactor KSR is within low adjectival rating range)
$x_7 >= 34$ and $x_7 <=66$ (Subfactor SIS is within moderate adjectival rating range)
$x_8 >= 67$ and $x_8 <=100$ (Subfactor PS is within low adjectival rating range)
$x_9 >= 67$ and $x_9 <=100$ (Subfactor PM is within low adjectival rating range)
****
For Cost/Price;
$x_{10} >= 67$ and $x_{10} <=100$ (CR is within low adjectival rating range)
****
For Past Performance;
$x_{11} >= 51$ and $x_{11} <=66$ (PP is within satisfactory adjectival rating range)

Sensitivity Analysis Model for Best/Worst Ratings within Color Ranges
(For Boeing in Version 2)

Decision Variables:

x_1	:	Mission Capability (MC) subfactor Key System Requirements (KSR) rating.
x_2	:	MC subfactor System Integration and Software (SIS) rating.
x_3	:	MC subfactor Product Support (PS) rating.
x_4	:	MC subfactor Program Management (PM) rating.
x_5	:	MC subfactor Technology Maturity and Demonstration (TMD) rating.
x_6	:	Proposal Risk (PR) subfactor Key System Requirements (KSR) rating.
x_7	:	PR subfactor System Integration and Software (SIS) rating.
x_8	:	PR subfactor Product Support (PS) rating.
x_9	:	PR subfactor Program Management (PM) rating.
x_{10}	:	Cost/Price subfactor Cost Risk (CR) rating.
x_{11}	:	Past Performance (PP) rating.

Objective Function (Linear Model):

Maximize
or
Minimize

$$\textit{Overall Score} = (0.3\,x_1 + 0.25\,x_2 + 0.2\,x_3 + 0.15\,x_4 + 0.1\,x_5)\,0.25 + (0.35\,x_6 + 0.3\,x_7 + 0.20\,x_8 + 0.15\,x_9)\,0.25 + 0.25\,x_{11} + 0.125 * 79 + (0.40\,x_{10} + 0.60 * 39.12)\,0.125$$

Constraints:

****
For Mission Capability;

$x_1 >= 66$ and $x_1 <=100$	(Subfactor KSR is within blue color rating range)
$x_2 >= 26$ and $x_2 <=65$	(Subfactor SIS is within green color rating range)
$x_3 >= 66$ and $x_3 <=100$	(Subfactor PS is within blue color rating range)
$x_4 >= 26$ and $x_4 <=65$	(Subfactor PM is within green color rating range)
$x_5 >= 61$ and $x_5 <=100$	(Subfactor TMD is within green color rating range)

****
For Proposal Risk;

$x_6 >= 61$ and $x_6 <=100$	(Subfactor KSR is within low adjectival rating range)
$x_7 >= 0$ and $x_7 <=60$	(Subfactor SIS is within moderate adjectival rating range)
$x_8 >= 61$ and $x_8 <=100$	(Subfactor PS is within low adjectival rating range)
$x_9 >= 61$ and $x_9 <=100$	(Subfactor PM is within low adjectival rating range)

****
For Cost/Price;

$x_{10} >= 0$ and $x_{10} <=60$	(CR is within moderate adjectival rating range)

****
For Past Performance;

$x_{11} >= 31$ and $x_{11} <=60$	(PP is within satisfactory adjectival rating range)

Sensitivity Analysis Model for Best/Worst Ratings within Color Ranges
(For Airbus in Version 2)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) rating.
x_2 : MC subfactor System Integration and Software (SIS) rating.
x_3 : MC subfactor Product Support (PS) rating.
x_4 : MC subfactor Program Management (PM) rating.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) rating.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) rating.
x_7 : PR subfactor System Integration and Software (SIS) rating.
x_8 : PR subfactor Product Support (PS) rating.
x_9 : PR subfactor Program Management (PM) rating.
x_{10} : Cost/Price subfactor Cost Risk (CR) rating.
x_{11} : Past Performance (PP) rating.

Objective Function (Linear Model):

Maximize or *Minimize* *Overall Score* =

$$(0.3\,x_1 + 0.25\,x_2 + 0.2\,x_3 + 0.15\,x_4 + 0.1\,x_5)\,0.25 + (0.35\,x_6 + 0.3\,x_7 + 0.20\,x_8 + 0.15\,x_9)\,0.25 + 0.25\,x_{11} + 0.125 * 90 + (0.40\,x_{10} + 0.60 * 39.8)\,0.125$$

Constraints:

****
For Mission Capability;
x_1 >= 66 and x_1 <=100 (Subfactor KSR is within blue color rating range)
x_2 >= 26 and x_2 <=65 (Subfactor SIS is within green color rating range)
x_3 >= 66 and x_3 <=100 (Subfactor PS is within blue color rating range)
x_4 >= 26 and x_4 <=65 (Subfactor PM is within green color rating range)
x_5 >= 61 and x_5 <=100 (Subfactor TMD is within green color rating range)
****
For Proposal Risk;
x_6 >= 61 and x_6 <=100 (Subfactor KSR is within low adjectival rating range)
x_7 >= 0 and x_7 <=60 (Subfactor SIS is within moderate adjectival rating range)
x_8 >= 61 and x_8 <=100 (Subfactor PS is within low adjectival rating range)
x_9 >= 61 and x_9 <=100 (Subfactor PM is within low adjectival rating range)
****
For Cost/Price;
x_{10} >= 61 and x_{10} <=100 (CR is within low adjectival rating range)
****
For Past Performance;
x_{11} >= 31 and x_{11} <=60 (PP is within satisfactory adjectival rating range)

Sensitivity Analysis Model for Best/Worst Ratings for Weight Changes
(For Boeing for Color Rating Method in Version 3)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) weight.
x_2 : MC subfactor System Integration and Software (SIS) weight.
x_3 : MC subfactor Product Support (PS) weight.
x_4 : MC subfactor Program Management (PM) weight.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) weight.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) weight.
x_7 : PR subfactor System Integration and Software (SIS) weight.
x_8 : PR subfactor Product Support (PS) weight.
x_9 : PR subfactor Program Management (PM) weight.
x_{10} : Cost/Price subfactor Life Cycle Cost (LCC) weight.
x_{11} : Cost/Price subfactor Cost Risk (CR) weight.
x_{12} : Mission Capability, Proposal Risk and Past Performance factors' weight.
x_{13} : Cost/Price and IFARA factors' weight.

Objective Function (Non-linear Model):

Maximize or *Minimize* *Overall Score* $= [(87.5\, x_1 + 62.5\, x_2 + 87.5\, x_3 + 62.5\, x_4 + 83.3\, x_5)]\, x_{12} + [(83.3\, x_6 + 50\, x_7 + 83.3\, x_8 + 83.3\, x_9)]\, x_{12} + 58.35\, x_{12} + 83.2\, x_{13} + (50\, x_{11} + 39.12\, x_{10})\, x_{13}$

Constraints:
****

For Mission Capability;

$x_1 > x_2$ (KSR is more important than SIS)
$x_2 > x_3$ (SIS is more important than PS)
$x_3 > x_4$ (PS is more important than PM)
$x_4 > x_5$ (PM is more important than TMD)
$x_5 > 0$ (all of the weights are bigger than 0)
$x_1 + x_2 + x_3 + x_4 + x_5 = 1$ (total of weights are equal to 1)

****

For Proposal Risk;

$x_6 > x_7$ (KSR is more important than SIS)
$x_7 > x_8$ (SIS is more important than PS)
$x_8 > x_9$ (PS is more important than PM)
$x_9 > 0$ (all of the weights are bigger than 0)
$x_6 + x_7 + x_8 + x_9 = 1$ (total of weights are equal to 1)

****

For Cost/Price;

$x_{10} > x_{11}$ (LCC is more important than CR)
$x_{11} > 0$ (all of the weights are bigger than 0)
$x_{10} + x_{11} = 1$ (total of weights are equal to 1)

****

For Factor Level;

$x_{12} > x_{13}$ (MC,PR and PP are more important than CR and IFARA)
$x_{13} > 0$ (all of the weights are bigger than 0)
$3\, x_{12} + 2\, x_{13} = 1$ (total of weights are equal to 1)

Sensitivity Analysis Model for Best/Worst Ratings for Weight Changes
(For Airbus for Color Rating Method in Version 3)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) weight.
x_2 : MC subfactor System Integration and Software (SIS) weight.
x_3 : MC subfactor Product Support (PS) weight.
x_4 : MC subfactor Program Management (PM) weight.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) weight.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) weight.
x_7 : PR subfactor System Integration and Software (SIS) weight.
x_8 : PR subfactor Product Support (PS) weight.
x_9 : PR subfactor Program Management (PM) weight.
x_{10} : Cost/Price subfactor Life Cycle Cost (LCC) weight.
x_{11} : Cost/Price subfactor Cost Risk (CR) weight.
x_{12} : Mission Capability, Proposal Risk and Past Performance factors' weight.
x_{13} : Cost/Price and IFARA factors' weight.

Objective Function (Non-linear Model):

Maximize or *Minimize*

$$\text{Overall Score} = [(87.5\,x_1 + 62.5\,x_2 + 87.5\,x_3 + 62.5\,x_4 + 83.3\,x_5)]\,x_{12} + [(83.3\,x_6 + 50\,x_7 + 83.3\,x_8 + 83.3\,x_9)]\,x_{12} + 58.35\,x_{12} + 92\,x_{13} + (83.3\,x_{11} + 39.8\,x_{10})\,x_{13}$$

Constraints:
****

For Mission Capability;

$x_1 > x_2$	(KSR is more important than SIS)
$x_2 > x_3$	(SIS is more important than PS)
$x_3 > x_4$	(PS is more important than PM)
$x_4 > x_5$	(PM is more important than TMD)
$x_5 > 0$	(all of the weights are bigger than 0)
$x_1 + x_2 + x_3 + x_4 + x_5 = 1$	(total of weights are equal to 1)

****

For Proposal Risk;

$x_6 > x_7$	(KSR is more important than SIS)
$x_7 > x_8$	(SIS is more important than PS)
$x_8 > x_9$	(PS is more important than PM)
$x_9 > 0$	(all of the weights are bigger than 0)
$x_6 + x_7 + x_8 + x_9 = 1$	(total of weights are equal to 1)

****

For Cost/Price;

$x_{10} > x_{11}$	(LCC is more important than CR)
$x_{11} > 0$	(all of the weights are bigger than 0)
$x_{10} + x_{11} = 1$	(total of weights are equal to 1)

****

For Factor Level;

$x_{12} > x_{13}$	(MC,PR and PP are more important than CR and IFARA)
$x_{13} > 0$	(all of the weights are bigger than 0)
$3\,x_{12} + 2\,x_{13} = 1$	(total of weights are equal to 1)

Sensitivity Analysis Model for Best/Worst Ratings for Weight Changes
(For Boeing for WSM Method in Version 3)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) weight.
x_2 : MC subfactor System Integration and Software (SIS) weight.
x_3 : MC subfactor Product Support (PS) weight.
x_4 : MC subfactor Program Management (PM) weight.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) weight.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) weight.
x_7 : PR subfactor System Integration and Software (SIS) weight.
x_8 : PR subfactor Product Support (PS) weight.
x_9 : PR subfactor Program Management (PM) weight.
x_{10} : Cost/Price subfactor Life Cycle Cost (LCC) weight.
x_{11} : Cost/Price subfactor Cost Risk (CR) weight.
x_{12} : Mission Capability, Proposal Risk and Past Performance factors' weight.
x_{13} : Cost/Price and IFARA factors' weight.

Objective Function (Non-linear Model):

Maximize *or* *Minimize* *Overall Score* $= [(93\,x_1 + 64\,x_2 + 92\,x_3 + 63\,x_4 + 94\,x_5)]\,x_{12} + [(94\,x_6 + 57\,x_7 + 97\,x_8 + 94\,x_9)]\,x_{12} + 59\,x_{12} + 83.2\,x_{13} + (58\,x_{11} + 39.12\,x_{10})\,x_{13}$

Constraints:
****
For Mission Capability;

$x_1 > x_2$	(KSR is more important than SIS)
$x_2 > x_3$	(SIS is more important than PS)
$x_3 > x_4$	(PS is more important than PM)
$x_4 > x_5$	(PM is more important than TMD)
$x_5 > 0$	(all of the weights are bigger than 0)
$x_1 + x_2 + x_3 + x_4 + x_5 = 1$	(total of weights are equal to 1)

****
For Proposal Risk;

$x_6 > x_7$	(KSR is more important than SIS)
$x_7 > x_8$	(SIS is more important than PS)
$x_8 > x_9$	(PS is more important than PM)
$x_9 > 0$	(all of the weights are bigger than 0)
$x_6 + x_7 + x_8 + x_9 = 1$	(total of weights are equal to 1)

****
For Cost/Price;

$x_{10} > x_{11}$	(LCC is more important than CR)
$x_{11} > 0$	(all of the weights are bigger than 0)
$x_{10} + x_{11} = 1$	(total of weights are equal to 1)

****
For Factor Level;

$x_{12} > x_{13}$	(MC,PR and PP are more important than CR and IFARA)
$x_{13} > 0$	(all of the weights are bigger than 0)
$3\,x_{12} + 2\,x_{13} = 1$	(total of weights are equal to 1)

Sensitivity Analysis Model for Best/Worst Ratings for Weight Changes
(For Airbus for WSM Method in Version 3)

Decision Variables:

x_1 : Mission Capability (MC) subfactor Key System Requirements (KSR) weight.
x_2 : MC subfactor System Integration and Software (SIS) weight.
x_3 : MC subfactor Product Support (PS) weight.
x_4 : MC subfactor Program Management (PM) weight.
x_5 : MC subfactor Technology Maturity and Demonstration (TMD) weight.
x_6 : Proposal Risk (PR) subfactor Key System Requirements (KSR) weight.
x_7 : PR subfactor System Integration and Software (SIS) weight.
x_8 : PR subfactor Product Support (PS) weight.
x_9 : PR subfactor Program Management (PM) weight.
x_{10} : Cost/Price subfactor Life Cycle Cost (LCC) weight.
x_{11} : Cost/Price subfactor Cost Risk (CR) weight.
x_{12} : Mission Capability, Proposal Risk and Past Performance factors' weight.
x_{13} : Cost/Price and IFARA factors' weight.

Objective Function (Non-linear Model):

Maximize *or* *Minimize* *Overall Score* $= [(81\,x_1 + 60\,x_2 + 90\,x_3 + 58\,x_4 + 85\,x_5)]\,x_{12} + [(85\,x_6 + 57\,x_7 + 91\,x_8 + 87\,x_9)]\,x_{12} + 56\,x_{12} + 92\,x_{13} + (70\,x_{11} + 39.8\,x_{10})\,x_{13}$

Constraints:
****
For Mission Capability;

$x_1 > x_2$ (KSR is more important than SIS)
$x_2 > x_3$ (SIS is more important than PS)
$x_3 > x_4$ (PS is more important than PM)
$x_4 > x_5$ (PM is more important than TMD)
$x_5 > 0$ (all of the weights are bigger than 0)
$x_1 + x_2 + x_3 + x_4 + x_5 = 1$ (total of weights are equal to 1)
****
For Proposal Risk;

$x_6 > x_7$ (KSR is more important than SIS)
$x_7 > x_8$ (SIS is more important than PS)
$x_8 > x_9$ (PS is more important than PM)
$x_9 > 0$ (all of the weights are bigger than 0)
$x_6 + x_7 + x_8 + x_9 = 1$ (total of weights are equal to 1)
****
For Cost/Price;

$x_{10} > x_{11}$ (LCC is more important than CR)
$x_{11} > 0$ (all of the weights are bigger than 0)
$x_{10} + x_{11} = 1$ (total of weights are equal to 1)
****
For Factor Level;

$x_{12} > x_{13}$ (MC,PR and PP are more important than CR and IFARA)
$x_{13} > 0$ (all of the weights are bigger than 0)
$3\,x_{12} + 2\,x_{13} = 1$ (total of weights are equal to 1)

Microsoft Excel Snapshot of Sensitivity Analysis Model for Best Rating within Color Ranges for Boeing in Version 1

MISSION CAPABILITY SUBFACTORS			WEIGHTS	WEIGHTED RATINGS
KSR	76-100	100	0.30	30.00
SIS	51-75	75	0.25	18.75
PS	76-100	100	0.20	20.00
PM	51-75	75	0.15	11.25
TMD	67-100	100	0.10	10.00
				90.00

PAST PERFORMANCE		RATING
SATISFACTORY	51-66	66.00
		66.00

IFARA	RATING
1.79	83.20
	83.20

PROPOSAL RISK SUBFACTORS			WEIGHTS	WEIGHTED RATINGS
KSR	67-100	100	0.35	35.00
SIS	34-66	66	0.30	19.80
PS	67-100	100	0.20	20.00
PM	67-100	100	0.15	15.00
				89.80

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	90.00	22.50
Proposal Risk	0.250	89.80	22.45
Past Performance	0.250	66.00	16.50
Cost/Price	0.125	49.87	6.23
IFARA	0.125	83.20	10.40
OVERALL OFFEROR RATING:			78.08

COST/PRICE SUBFACTORS			WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	N\A	0.60	39.12	23.47
RISK	66	34-66	0.40	66.00	26.40
					49.87

Microsoft Excel Snapshot of Sensitivity Analysis Model for Best Rating within Color Ranges for Boeing in Version 2

MISSION CAPABILITY SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	100	0.30	30.00
SIS	65	0.25	16.25
PS	100	0.20	20.00
PM	65	0.15	9.75
TMD	100	0.10	10.00
			86.00

PAST PERFORMANCE	RATING
60	60.00

IFARA	RATING
1.79	79.00
	79.00

PROPOSAL RISK SUBFACTORS		WEIGHTS	WEIGHTED RATINGS
KSR	100	0.35	35.00
SIS	60	0.30	18.00
PS	100	0.20	20.00
PM	100	0.15	15.00
			88.00

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.250	86.00	21.50
Proposal Risk	0.250	88.00	22.00
Past Performance	0.250	60.00	15.00
Cost/Price	0.125	47.47	5.93
IFARA	0.125	79.00	9.88
OVERALL OFFEROR RATING:			74.31

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.60	39.12	23.47
RISK	60	0.40	60.00	24.00
				47.47

Microsoft Excel Snapshot of Sensitivity Analysis Model for Best Rating for Weight Changes for Boeing for Color Rating Method In Version 3

MISSION CAPABILITY SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.90	87.5	78.75
SIS	GREEN	0.04	62.5	2.50
PS	BLUE	0.03	87.5	2.62
PM	GREEN	0.02	62.5	1.25
TMD	GREEN	0.01	83.3	0.83
		1.00		85.96

PAST PERFORMANCE	RATING
SATISFACTORY	58.35
	58.35

IFARA	RATING
1.79	83.20
	83.20

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.94	83.3	78.30
SIS	MODERATE	0.03	50	1.50
PS	LOW	0.02	83.3	1.67
PM	LOW	0.01	83.3	0.83
		1.00		82.30

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.327	85.96	28.08
Proposal Risk	0.327	82.30	26.88
Past Performance	0.327	58.35	19.06
Cost/Price	0.010	44.51	0.45
IFARA	0.010	83.20	0.83
	1.000		75.30

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.51	39.12	19.76
RISK	MODERATE	0.50	50	24.75
		1.00		44.51

BOEING COLOR ORIGINAL 68.02

Microsoft Excel Snapshot of Sensitivity Analysis Model for Best Rating for Weight Changes for Boeing for WSM Method in Version 3

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	N/A	0.90	93	83.70
SIS		0.04	64	2.56
PS		0.03	92	2.76
PM		0.02	63	1.26
TMD		0.01	94	0.94
		1.00		91.22

PAST PERFORMANCE	RATING
N/A	59.00
	59.00

IFARA	RATING
1.79	83.20
	83.20

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	N/A	0.94	94	88.36
SIS		0.03	57	1.71
PS		0.02	97	1.94
PM		0.01	94	0.94
		1.00		92.95

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.327	91.22	29.80
Proposal Risk	0.327	92.95	30.36
Past Performance	0.327	59.00	19.27
Cost/Price	0.010	48.47	0.48
IFARA	0.010	83.20	0.83
	1.000		80.75

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.51	39.12	19.76
RISK	N/A	0.50	58	28.71
		1.00		48.47

BOEING WSM ORIGINAL 72.15

Sensitivity Analysis Boeing's Best Case Scenario Weights in Color Rating Method Applied to Airbus

BOEING

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.90	87.5	78.75
SIS	GREEN	0.04	62.5	2.50
PS	BLUE	0.03	87.5	2.62
PM	GREEN	0.02	62.5	1.25
TMD	GREEN	0.01	83.3	0.83
		1.00		85.96

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.94	83.3	78.30
SIS	MODERATE	0.03	50	1.50
PS	LOW	0.02	83.3	1.67
PM	LOW	0.01	83.3	0.83
		1.00		82.30

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.51	39.12	19.76
RISK	MODERATE	0.50	50	24.75
		1.00		44.51

PAST PERFORMANCE	RATING	IFARA	RATING
SATISFACTORY	58.35	1.79	83.20
	58.35		83.20

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.327	85.96	28.08
Proposal Risk	0.327	82.30	26.88
Past Performance	0.327	58.35	19.06
Cost/Price	0.010	44.51	0.45
IFARA	0.010	83.20	0.83
	1.000		75.30

BOEING COLOR ORIGINAL 68.019

AIRBUS

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.90	87.5	78.75
SIS	GREEN	0.04	62.5	2.50
PS	BLUE	0.03	87.5	2.62
PM	GREEN	0.02	62.5	1.25
TMD	GREEN	0.01	83.3	0.83
		1.00		85.96

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.94	83.3	78.30
SIS	MODERATE	0.03	50	1.50
PS	LOW	0.02	83.3	1.67
PM	LOW	0.01	83.3	0.83
		1.00		82.30

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.01	0.51	39.8	20.10
RISK	LOW	0.50	83.3	41.23
		1.00		61.33

PAST PERFORMANCE	RATING	IFARA	RATING
SATISFACTORY	58.35	1.9	92.00
	58.35		92.00

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.327	85.96	28.08
Proposal Risk	0.327	82.30	26.88
Past Performance	0.327	58.35	19.06
Cost/Price	0.010	61.33	0.61
IFARA	0.010	92.00	0.92
	1.000		75.56

AIRBUS COLOR ORIGINAL 70.835

Sensitivity Analysis Airbus's Best Case Scenario Weights in Color Rating Method Applied to Boeing

AIRBUS

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.90	87.5	78.75
SIS	GREEN	0.04	62.5	2.50
PS	BLUE	0.03	87.5	2.62
PM	GREEN	0.02	62.5	1.25
TMD	GREEN	0.01	83.3	0.83
		1.00		85.96

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.94	83.3	78.30
SIS	MODERATE	0.03	50	1.50
PS	LOW	0.02	83.3	1.67
PM	LOW	0.01	83.3	0.83
		1.00		82.30

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.01	0.51	39.8	20.10
RISK	LOW	0.50	83.3	41.23
		1.00		61.33

PAST PERFORMANCE	RATING	IFARA	RATING
SATISFACTORY	58.35	1.9	92.00
	58.35		92.00

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.204	85.96	17.54
Proposal Risk	0.204	82.30	16.79
Past Performance	0.204	58.35	11.90
Cost/Price	0.194	61.33	11.90
IFARA	0.194	92.00	17.85
	1.000		75.97

AIRBUS COLOR ORIGINAL 70.835

BOEING

MISSION CAPABILITY		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	BLUE	0.90	87.5	78.75
SIS	GREEN	0.04	62.5	2.50
PS	BLUE	0.03	87.5	2.62
PM	GREEN	0.02	62.5	1.25
TMD	GREEN	0.01	83.3	0.83
		1.00		85.96

PROPOSAL RISK SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
KSR	LOW	0.94	83.3	78.30
SIS	MODERATE	0.03	50	1.50
PS	LOW	0.02	83.3	1.67
PM	LOW	0.01	83.3	0.83
		1.00		82.30

COST/PRICE SUBFACTORS		WEIGHTS	RATINGS	WEIGHTED RATINGS
COST	108.044	0.51	39.12	19.76
RISK	MODERATE	0.50	50	24.75
		1.00		44.51

PAST PERFORMANCE	RATING	IFARA	RATING
SATISFACTORY	58.35	1.79	83.20
	58.35		83.20

FACTORS	WEIGHTS	RATING	WEIGHTED RATING
Mission Capability	0.204	85.96	17.54
Proposal Risk	0.204	82.30	16.79
Past Performance	0.204	58.35	11.90
Cost/Price	0.194	44.51	8.63
IFARA	0.194	83.20	16.14
	1.000		71.00

BOEING COLOR ORIGINAL 68.019

Sensitivity Analysis 1 Results Summary Table

VERSION 1	BOEING	AIRBUS	DIFFERENCE	OVERLAPPING RANGES
MAX	78.084	80.935	2.851	16.949
MIN	58.334	61.135	2.801	
	19.75	19.8		

Sensitivity Analysis 2 Results Summary Table

VERSION 2	BOEING	AIRBUS	DIFFERENCE	OVERLAPPING RANGES
MAX	74.309	77.735	3.426	26.224
MIN	43.609	48.085	4.476	
	30.7	29.65		

Sensitivity Analysis 3 Results Summary Table

	COLOR MAX	COLOR MIN	WSM MAX	WSM MIN
BOEING	75.30	65.04	80.75	67.38
	ORIGINAL 68.02		ORIGINAL 72.15	
AIRBUS	75.97	66.95	73.44	66.18
	ORIGINAL 70.84		ORIGINAL 70.14	

	COLOR WEIGHT RANGE	WSM WEIGHT RANGE
BOEING	10.26	13.38
AIRBUS	9.02	7.26

BOEING'S BEST RESULT RATINGS VS. AIRBUS WITH SAME WEIGHTS		
	COLOR	WSM
BOEING	75.30	80.75
AIRBUS	75.56	73.44

AIRBUS'S BEST RESULT RATINGS VS. BOEING WITH SAME WEIGHTS		
	COLOR	WSM
BOEING	71.00	80.75
AIRBUS	75.97	73.44

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